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SECOND SESSION, FORTY-THIRD CONGRESS.

EXECUTIVE DOCUMENTS

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TO

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FOR THE

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43D CONGRESS, 2d Session. } HOUSE OF REPRESENTATIVES. { Ex. Doc. 1, Part 2.

REPORT

OF THE

SECRETARY OF WAR;

BEING PART OF

THE MESSAGE AND DOCUMENTS

COMMUNICATED TO THE

TWO HOUSES OF CONGRESS

AT THE

BEGINNING OF THE SECOND SESSION OF THE FORTY-THIRD CONGRESS.

VOLUME II.
PART II.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1874.

APPENDIXES

TO THE

REPORT OF THE CHIEF OF ENGINEERS,

(CONTINUED.)

APPENDIXES

TO THE

REPORT OF THE CHIEF OF ENGINEERS,

(CONTINUED.)

APPENDIX T.

ANNUAL REPORT OF LIEUTENANT COLONEL Q. A. GILLMORE, CORPS OF ENGINEERS, FOR THE FISCAL YEAR ENDING JUNE 30, 1874.

UNITED STATES ENGINEER OFFICE,
New York, August 28, 1874.

GENERAL: I have the honor to submit herewith my annual report upon the several works of surveys and examinations and harbor improvements under my charge.

The reports show the operations carried on during fiscal year ending June 30, 1874; the operations contemplated during fiscal year ending June 30, 1875; and estimates for the year ending June 30, 1876.

The operations of the United States dredging-steamer Henry Burden are made the subject of a separate report.

Very respectfully, general, your obedient servant,

Q. A. GILLMORE,
Lieut. Col. of Engineers, Bvt. Maj. Gen.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

T 1.

IMPROVEMENT OF THE SHIP-CHANNEL IN CHARLESTON HARBOR, SOUTH CAROLINA.

The project for this work comprised the removal of sundry wrecks sunk in the harbor during the civil war, the removal of 125 linear feet from the outer end of the Bowman jetty, projecting from Sullivan's Island into Beach Channel, and dredging in that channel to a depth of 15 feet low-water soundings.

The estimated cost of these improvements was $74,000 to $76,000. There has been appropriated $74,700.

During the past fiscal year the work accomplished comprised the removal of only 738 cubic yards of stone from the outer end of Bowman's jetty, most of which was placed on or alongside the shore end of the

same, and 122 cubic yards was deposited in deep water to the west of the channel end of the jetty. This work does not progress as rapidly as was expected, in consequence of the strong currents which exist there at all stages of the tide except for a couple of hours at slack-water of ebb and flood tide. The contractors at work on the jetty are Mr. Joel Griffin, under a contract entered into on the 30th of September, 1872, and Mr. Benjamin Maillefert, under a contract entered into on the 8th of May, 1874. There were also removed, under a contract with Mr. Benj. Maillefert, entered into on the 16th of September, 1873, the wrecks of the Stono, the Prince of Wales, and the Juno, lying close to the Bowman jetty on the east side.

Under a contract executed April 15, 1873, Mr. Benj. Maillefert removed the wreck of the monitor Keokuk, sunk in the main channel abreast of Morris Island, and purchased by him for the sum of $50.

My assistant, Capt. J. W. Cuyler, Corps of Engineers, in reporting upon the progress of the work of removing Bowman's jetty, says:

> Mr. Griffin raises his stone by a pair of grappling-irons, worked by a whip by man-power, on a small flat, and can raise stone from 1½ to 2½ cubic yards in size. Mr. Maillefert works on a larger scale, using a large scow, on which is a heavy "tongs" or set of claws, run by steam-power, and can take up stone from 3 to 4 cubic yards in size. The locality is most unfavorable for this work. Owing to exposure to heavy seas and a contracted channel-way, giving strong currents, varying with the winds and the different stages of the tide, it was found impossible to do any work but for about an hour on either side of the slack-water time, so that the work has progressed but slowly; scarcely as rapidly as the importance of it called for. To meet this requirement, it is deemed that appliances more perfect than those now in use, and the carrying on of operations on a more extended scale, are requisite—indeed indispensable.

No dredging was done during the past fiscal year in Beach Channel, it having been thought best to defer this work until the end of the jetty was removed to a depth of 16½ feet below low-water, in order that the benefit of the increased flow to be secured thereby might be realized.

During the present fiscal year the work of removing the end of Bowman's jetty will be continued, and probably completed to a depth of 16½ feet below low-water, over that portion comprising 125 linear feet of its outer end, as first estimated.

Dredging in Beach Channel to secure the desired depth of 15 feet at mean low-water will also be carried on, and possibly completed. The time of its completion will depend on whether the work is done by contract or by the United States dredging-steamer Henry Burden. If by the latter, it will be prosecuted in connection with dredging elsewhere, the magnitude of which cannot be stated in anticipation of proposals from contractors. Beach Channel is essentially a flood-tide channel; the tidal wave in entering it meets with no sudden bar to obstruct its flow until it reaches Drunken Dick Shoal and the contracted waterway between this shoal and Fort Moultrie, where the Bowman jetty is located. A vessel entering this channel from the ocean, after reaching four fathoms of water off Rattlesnake Shoals, six miles distant from Fort Moultrie, would gradually and quite regularly shoal her soundings until she arrived at the narrow pass between the end of Bowman jetty and Drunken Dick Shoal, where she would encounter a narrow channel a little less than 15 feet deep, with a sharp turn to the southward, caused by the projecting end of the jetty. It is expected that the removal of the outer end of this jetty will result in straightening the channel without any diminution of depth, and it is hoped that any additional width and depth secured in the narrow pass by dredging will be permanent. The direction of Beach Channel, with the exception of the sudden turn above mentioned, is due east and west. The turn is

expected to disappear, in great measure, with the removal of the outer portion of the jetty, upon which work is now in progress. The direction of the flood-current through Beach Channel is, therefore, due west. When it reaches the inner end of that channel, at the jetty, it meets the main volume of the flood through the main ship, the north, and the swash channels, and is diverted in a northwesterly direction, parallel to that portion of Sullivan's Island west of Fort Moultrie, and flows thence through Rebellion Roads and Hog Island Channel. On the ebb this large volume of water, constituting, perhaps, three-fourths of the entire ebb-flow in the harbor, takes the opposite or southeasterly direction, and, passing by the narrow inner end of the Beach Channel, flows to the sea through the several channels farther south. One of the objects of shortening Bowman jetty is, therefore, to increase the volume of ebb flowing through Beach Channel. In the original project for the improvement of this harbor, submitted in my communication of May 13, 1871, it was stated that—

> Should the removal of 125 feet from the end of Bowman jetty be executed with such results as to suggest a further reduction in the length of that work, an additional appropriation will be requested.

Over this section of 125 feet a depth in no place less than 11½ feet at mean low-water was attained during the last fiscal year, resulting in such an increase in the volume of flow on the ebb-tide that I am induced to recommend a further reduction of 50 feet in the length of the jetty, at an estimated cost of $10,000, inclusive of the necessary additional dredging.

Within the last few weeks the municipal authorities of the city of Charleston have taken some important steps towards the improvement of Pumpkin Hill Channel across the main bar, opposite the lower end of Morris Island. This channel is the one now exclusively used by large vessels. It is run by range-lights on Morris Island. A contract has been entered into between the city authorities and Mr. Benjamin Maillefert, under which the latter agrees to establish a channel 20 feet deep at mean high-water, and of a specified width. I entertain no doubt of the practicability of dredging such a channel with a centrifugal pump, which the contractor intends to use, substantially as now employed upon the steamer Henry Burden.

Experience will indicate whether the annual cost of maintaining such a channel at that point will be too great to justify the General Government in assuming it.

The contemplated depth of 20 feet at mean high-water (or 15 feet at mean low-water) is the same as that adopted in the project for improving Beach Channel. But 20 feet in Beach Channel is equivalent to nearly, if not quite, 22 feet on Pumpkin Hill, owing to the much greater swell always existing at the last-named locality. A vessel drawing 18 feet of water would require an exceptionably quiet sea in order to pass through Pumpkin Hill Channel on 20-feet soundings without striking the bottom, while she could ordinarily pass Beach Channel on 18½ to 19 feet soundings.

Financial statement.

Balance in Treasury of the United States July 1, 1873	$26,700 00
Amount in hands of officer and subject to his check	9,142 44
Amount appropriated by act approved June 23, 1874	18,000 00
Amount expended during fiscal year ending June 30, 1874	20,018 57
Amount available July 1, 1874	30,573 87
Amount required for the fiscal year ending June 30, 1876	10,000 00

T 2.

IMPROVEMENT OF SAVANNAH RIVER AND HARBOR, GEORGIA.

The annual report of the progress made in the improvement of Savannah River, during the fiscal year ending June 30, 1873, embraced a project—

Having in view the ultimate achievement of a practicable low-water ship-channel 15 feet in depth, or, rather, a channel by which vessels drawing 22 feet of water can pass on the high-tide from Tybee Roads, where the mean rise and fall is 7 feet, to Savannah City, where the mean rise and fall is only 6¼ feet.

It was stated that the estimated cost of carrying out the entire project was $481,320, and that the general plan could be extended and a greater channel-depth attained, if it should be found expedient to do so.

OPERATIONS DURING THE YEAR.

The operations during the past fiscal year, although conducted in furtherance of the project referred to above, were not included in the general estimate. They consisted in dredging at various points, and in removing sundry wrecks and other obstructions as specified below.

1. Northeast of Fort Pulaski, and south of the light-ship, 55,369 cubic yards of materials have been removed from a shoal or bar which separates Tybee Roads from the channel passing between the oyster-bed and Fort Pulaski. The channel established over this shoal is 13 feet deep and nearly 200 feet wide at mean low-water.

Most of the dredging in this locality was done by the United States dredge-steamer Henry Burden, and it was found convenient and deemed expedient to make the channel considerably wider than was contemplated when the project for the fiscal year was submitted.

2. Abreast of Elba Island a long shoal exists from which 57,688 cubic yards of materials were removed, and a channel 13¼ feet deep and fully 100 feet wide at mean low-water secured.

Upon this shoal the work done was fully double the quantity estimated for and set forth in the specifications, a large deposit of silt having taken place between the time when the survey used in the calculations for the work was made and the period of commencing the dredging. At other points, notably opposite the lower end of Elba Island, and also opposite the upper end of Long Island, the shoals have been removed to such a degree by the scouring action of the water that no dredging has yet been necessary, and none is contemplated during the present fiscal year, or under the appropriation made in the act approved June 23, 1874.

3. At the place known as The Wrecks, opposite the lower end of Fig Island, 2,436 cubic yards of materials have been removed. Of the 115,493 cubic yards of dredging accomplished during the year, 45,607 cubic yards were taken out by the United States dredge-steamer Henry Burden from the shoal northeast of Fort Pulaski, and the balance, 69,886 cubic yards, by the city of Savannah under contract. (A full report of the work done by the steamer Henry Burden during the year is given in a statement by itself.) No dredging was done upon Garden Bank opposite the city of Savannah.

4. The wrecks of two large wooden vessels of 1,000 to 1,200 tons burden each (the Thompson and the Sebastecook) were removed from the channel northwest of Fort Pulaski, near the oyster-bed beacon. This work was done under a special agreement entered into with Mr. David Symons, on the authority of the Chief of Engineers. A lighter

loaded with oyster-shells for Fort Pulaski, sunk in the channel opposite that work, was also removed by Mr. Symons, under authority from the Chief of Engineers.

WORK CONTEMPLATED DURING THE PRESENT FISCAL YEAR.

The act approved June 23, 1874, appropriated $50,000 for continuing the improvement of the harbor of Savannah. It is proposed to expend this sum substantially as follows, although all the work specified may not be completed during the fiscal year, viz:

1. In dredging 20,000 to 25,000 cubic yards from the shoal northeast of Fort Pulaski in order to establish a channel 13½ feet deep and 150 feet wide at mean low-water. It is probable that the width will exceed 150 feet.

2. In dredging 25,000 to 30,000 cubic yards from the shoal abreast of Elba Island so as to secure at that point a channel 13½ feet deep and 125 feet wide at mean low-water.

3. In dredging 35,000 to 40,000 cubic yards at "The Wrecks," opposite the lower end of Fig Island, so as to secure a channel 13¾ feet deep and 125 feet wide at mean low-water.

4. In dredging 30,000 to 38,000 cubic yards from Garden Bank, opposite the lower portion of the city of Savannah, so as to establish along the city wharves a channel 13¾ feet deep and not less than 125 feet wide in that locality.

5. In removing one crib sunk during the civil war in the channel at the entrance from the Savannah River into St. Augustine Creek.

This channel was closed by a line of heavy cribs and piles, many of which have already been taken out. It is not proposed to remove them all, but to widen the existing opening for the accommodation of steamers and small sailing-vessels using the inside passage from Savannah to Brunswick and farther south.

At both Garden Bank and "The Wrecks" the natural causes at work have a tendency to fill up the channel. The obvious remedy for this evil is to increase the volume of flow in the stream by means of a dam or a deflecting jetty at "Cross-Tides" in conjunction, if necessary, with a contraction of the water-way by means of longitudinal jetties wherever needed.

The project submitted last year contemplates both of these classes of works, and I deem it extremely doubtful whether the channel will maintain itself at the necessary depth without a resort to them.

An essential feature of that project is a dam at "Cross-Tides" with a sluice-way for river-boats, or in lieu thereof a deflecting jetty, the object in either case being to force into Front River along the wharves of the city of Savannah a portion of the large volume of water which now passes into Back River through the Cross-Tides, four miles above the city, and joins the Savannah River again below Fig Island and one mile below the lower city limits.

Nearly two-thirds of the water coming down the Savannah River flows through the "Cross-Tides" into Back River, while only one-third of it passes down Front River past the city wharves and over the shoals known as Garden Bank and "The Wrecks," that are such serious obstructions to navigation.

I entertain grave doubts of the stability of any channel established over these shoals by dredging alone, unaided by suitable works for augmenting the volume of flow.

I therefore deem the construction of the work projected at "Cross-

Tides," either a deflecting jetty or a sluice-dam—preferably the latter—as of capital importance.

In order to secure the construction of this work, and at the same time carry on the necessary improvement by dredging at points lower down, a liberal appropriation is recommended.

It is not improbable that after the jetty or dam is finished it will be found necessary to contract the natural water-way at some points in order to establish a more rapid current over the shoals.

In my judgment the work at "Cross-Tides" should first be constructed. This will result in an increased volume of water to deal with at the shoals below. The measure of this increase will determine the method of improvement likely to prove the most advantageous.

The omission of this dam from the scheme of proposed improvement will in my opinion materially enhance the total cost of the projected works, for not only will the scouring effects of the increased flow to be established by the dam be wanting, but, to compensate for its absence, the contraction of the channel with longitudinal jetties in order to create an ebb current of the requisite velocity to keep the channel open may have to be resorted to, on a scale not estimated for or deemed necessary on the hypothesis of a dam at "Cross-Tides."

Even the postponement of the construction of this deflection jetty or dam until the heaviest part of the dredging is done on the shoals at and below the city will increase the cost of completing the works.

Its construction at the earliest practicable moment is urged as a measure of economy.

The detailed estimate of the total cost of the proposed improvements, together with a table of statistics showing the steady increase of the commerce of the city of Savannah, was included in my last annual report.

Financial statement.

Balance in Treasury of United States July 1, 1873	$70,000 00
Amount in hands of officer and subject to his check	1,805 64
Amount appropriated by act approved June 23, 1874	50,000 00
Amount expended during fiscal year ending June 30, 1874	71,149 55
Amount available July 1, 1874	50,656 09
Amount required for fiscal year ending June 30, 1876	175,000 00
Additional amount which will be required to complete the project	256,320 00

T 3.

IMPROVEMENT OF THE BAR AT THE MOUTH OF THE ST. JOHN'S RIVER, FLORIDA.

The temporary improvement of the ship-channel across the St. John's River Bar, by dredging, was carried on during a period of fifteen weeks, with the United States dredging-steamer Henry Burden, fully described in my previous reports, more particularly in the annual report of the Chief of Engineers for the fiscal year ending June 30, 1872.

At the time work was begun, on September 29, 1873, it was found that many changes had taken place since the suspension of work the previous November. The portion dredged in south channel had shoaled considerably, and had become crooked and elongated, while the channel north of Pelican Bank had scoured out to such a degree that, in respect to depth of water, there was only a few inches difference in favor of the south channel.

The north channel being much the shortest of the two, and in all respects quite as accessible and convenient for vessels, seemed to offer

the best promise of useful results with the small sum available for the work. It was therefore selected as the one to be dredged.

The total quantity of sand removed between September 29, 1873, and January 10, 1874, when work was suspended, was 14,649 cubic yards.

The amount expended in running-expenses, current repairs, and alterations was $3,915.59, or an average of 26$\frac{5}{7}$ cents per cubic yard. I am not prepared to say that the work done resulted in any material improvement of the channel. The season was exceptionably bad for dredging, and the interruptions from storms and heavy fogs frequent and sometimes prolonged. The consequence was that the increased depth achieved from time to time during the few periods of comparatively continuous work which the weather allowed was filled in by the succeeding storms, and the channel restored to its normal condition, if such a term can be applied to a water-way possessing no stability and liable to be changed, not only in its position and direction but in its depth also, by every storm that occurs upon the coast, no matter from what direction it may proceed.

It has never been assumed nor supposed that dredging in the channel across the Saint John's bar would result in any permanent improvement. On the contrary, the constantly shifting character of this bar has been admitted from the first, and discussed at some length in my annual reports.

The only kind of permanent improvement which is at all applicable to the mouth of this river, with any promise of success, is the method of jetties; and even jetties, although judiciously located and well constructed, might signally fail to give that measure of relief which is desired.

It is claimed by parties interested in the growth of Jacksonville, and in the trade naturally tributary to the St. John's River, that a large amount of freight from the West will seek ocean transportation by way of that stream as soon as the Jacksonville, Pensacola and Mobile Railroad, having its eastern terminus at Jacksonville, shall have formed its contemplated western connections; and that it will then be demanded of the General Government, in the furtherance of what is understood to be its general policy of internal improvements, to expend money liberally for permanent works of improvement, either at the mouth of the St. John's, or, as an alternative, upon a ship-channel or canal for large vessels between that river and Nassau Inlet, or even Fernandina.

The soundness of these views may well be questioned; for a glance at the map will show that eastern-bound freight from all points west of the Apalachicola River would naturally seek Mobile or Pensacola as a shipping-port in preference to a harbor on the Atlantic coast, the saving in distance by rail being more than sufficient to compensate for the lengthened voyage by sea.

It would appear, therefore, that only the middle and eastern portions of Florida, and that part of Georgia beyond reach of the railroad-system, whose tide water connection is at Brunswick, could afford to send its productions to the St. John's River for shipment. But conceding that this is not the case, and that at an early day, or as soon as certain projected roads are completed, the amount of freight brought to tide-water on the Atlantic by the Jacksonville, Pensacola and Mobile Railroad and the Florida Railroad will require a harbor with ample depth of water for large sea-going vessels. Even under this hypothesis it does not necessarily follow that the requisite facilities for transshipment should be supplied by the General Government on the St. John's River.

From the west it is only twenty-six miles farther by rail to Fernandina, where an excellent harbor exists and no improvements are necessary,

than it is to Jacksonville. The harbor of Fernandina is accessible to vessels drawing eighteen feet of water.

The expenditure of from $750,000 to $1,000,000 in the construction of a ship-channel or canal from the St. John's River to Fernandina would doubtless also render the St. John's accessible to ocean-going vessels of sufficient capacity to transport their cargoes at low rates.

The distance from Fernandina to Jacksonville, along the route generally conceded to be the best for a canal, is fifty-two miles, of which twenty-two miles would be the St. John's River itself, improved at certain points, and twenty-six miles the existing inside passage considerably improved by widening, deepening, and straightening at sundry points.

The balance of four miles would be made up of artificial channels excavated through the marshes and low-lands, at such places and in such directions as would result in the greatest reduction in the length of the line.

I have never been an advocate for jetties at the mouth of the St. John's River, having no confidence in the practicability of their construction and maintenance at a reasonable cost, and no belief in either the certainty or the magnitude of the benefit to be derived from them. Upon these points I am not able to form any judgment upon which I am willing to rely myself, much less to advance or recommend officially.

It would seem, therefore, that the question which presents itself for solution in this connection is whether the United States shall construct and maintain permanent works of improvement at an original outlay of nearly, if not quite, $1,000,000, in order that the trifling difference between the cost of twenty-six miles of railroad transportation and fifty-two miles' carriage by water may be saved to the producers located within a very restricted area of country. I am not prepared to advocate such a policy.

Assuming, therefore, that the General Government will not deem it expedient to enlarge into a ship-channel for large ocean-going vessels the present inland passage between Fernandina and St. John's River, the next question is whether any expenditure at all can be wisely made upon that route.

The passage is at the present time navigable for small steamers and is used by them constantly.

A survey or examination of that portion of this line south of Nassau Inlet, was provided for by the act of Congress approved June 23, 1874, and the appropriation of $10,000 by the same act, for the improvement of the bar at the mouth of the St. John's River, was made applicable to the improvement of this passage.

From my knowledge of this channel, derived from pilots and masters of vessels, and the necessity for its constant use by small steamers plying between Savannah and Jacksonville, for the accommodation of towns and planters along the route, I deem its improvement to a limited extent by the United States, to be entirely legitimate and proper. It will doubtless be found expedient and desirable to continue its improvement from time to time, until it is brought to such condition that all the river-craft plying upon the St. John's River above Jacksonville can reach Fernandina and discharge and receive cargoes at that point. The commerce of the St. John's is steadily increasing in magnitude and importance, and the amount of freight brought down the stream and arriving at Jacksonville by rail, for transshipment to foreign or domestic ports, is by no means inconsiderable.

At the present time it has to be exported in small vessels, upon which the freight-charges are comparatively high. The freight arriving by

rail can, of course, avoid this by going to Fernandina, but is to a large extent prevented taking that direction by local competition and jealousy.

The natural and proper port for the shipment of all freight arriving in East Florida, by either the Jacksonville, Pensacola and Mobile, or by the Florida Railroad, and seeking transportation in large vessels, is Fernandina, and the inside passage should be enlarged to such degree that the St. John's River boats and barges can deliver their cargoes at this point in all cases when the shipment by small vessels arriving and departing by way of the St. John's Bar is deemed relatively disadvantageous.

I doubt the wisdom of expending any more money upon the bar at the mouth of the St. John's River.

As soon as practicable after the survey of the inside passage provided for at the last session of Congress shall have been completed, a project for its improvement will be submitted, with estimates of its cost.

The amount appropriated for the fiscal year ending June 30, 1875, is $10,000, which can be applied to continuing the work on the bar, or to dredging out the inside passage between the St. John's River and Nassau Inlet.

I recommend for the fiscal year ending June 30, 1876, an appropriation of $15,000, to be applied to such improvement of the inside passage referred to as the contemplated survey may show to be feasible and desirable, or in the event of the impracticability of any improvement of this passage at a reasonable cost to be used upon the bar.

Financial statement.

Balance in Treasury of United States July 1, 1873	$10,000 00
Deduct amount expended during the fiscal year ending June 30, 1874	77 63
Amount appropriated by act approved June 23, 1874	10,000 00
Amount expended during fiscal year ending June 30, 1874	9,922 37
Amount available July 1, 1874	10,000 00
Amount required for the fiscal year ending June 30, 1876	15,000 00

T 4.

OPERATIONS OF UNITED STATES DREDGING—STEAMER HENRY BURDEN.

UNITED STATES ENGINEER OFFICE,
New York, August 3, 1874.

GENERAL: I have the honor to submit below a brief statement of the operations of the United States dredging-steamer Henry Burden for the fiscal year ending June 30, 1874, as supplementary to my annual reports upon the river and harbor improvements under my charge.

As previously described, the Henry Burden is a small side-wheel steamer, fitted up with a 9-inch centrifugal pump, two branches of 6-inch suction-hose, and timber-bins with sliding gates on deck for holding the materials raised from the bottom.

The pump-engine is connected with the steamer's boiler. The materials pumped up from the bottom are washed overboard at the dumping ground by running the pump in clear water.

The steamer was purchased under authority from the War Department, and taken possession of on the 20th of August, 1873. The dredging-apparatus had been placed on board two years before, while the vessel was under charter to the United States.

The steamer sailed from New York on the 27th of August and reached Savannah on the 30th, making the passage in eighty hours, during which

she encountered a storm which thoroughly tested and proved her seaworthiness.

During the early part of the month of September she was engaged in experimental work at different points of the Savannah River upon the various kinds of materials, such as sand, mud, and a mixture of the two, composing the bars and shoals in that stream, that required removal.

While engaged in these trials the crew became so disabled by malarial fever that it was deemed expedient to defer all dredging-operations upon the Savannah River, except those carried on by the contractor, until the sickly season had passed.

The steamer was therefore ordered to the bar at the mouth of the St. John's River, Florida, where dredging was commenced on the 29th of September, and continued until the appropriation was exhausted on the 10th of January, 1874.

Owing to exceptionally bad and foggy weather—the season being described by pilots as the most inclement known in the locality for thirty years—only fifty-seven working-days, averaging five hours each, were secured. In this time 14,649 cubic yards of sand was raised from the bar and dumped in deep water, or about 51⅓ cubic yards per hour.

The cost of this dredging per year, as compared with the cost during two previous years, while the vessel was under charter, is shown in the following table:

	1871–'72.	1872–'73.	1873–'74.
Least cost during any one day, per cubic yard	$0 13	$0 15	$0 8 4-10
Least cost during any one week, per cubic yard	19	19 1-2	14 1-8
Least cost during any one month, per cubic yard	26	23 1-2	16
Average cost for the entire period	52 3-5	31 1-8	26 5-7

These figures cover all current expenses for superintendence, wages, and subsistence of officers and crew, (twelve persons in all,) fuel, repairs, and supplies.

From these results, obtained during a short season of almost unexampled inclemency, I judge that, even in so exposed a position as the St. John's Bar, the Henry Burden, taking one year with another, can remove upward of 80,000 cubic yards of material per year, at a cost not much, if at all, exceeding 20 cents per cubic yard.

On the 15th of January the steamer was transferred to the Savannah River, and dredging was commenced on the shoal known as the "Knoll," northeast of Fort Pulaski, and continued until the end of the fiscal year. Twenty-one days were lost on account of bad weather, trips to Savannah for fuel, &c., and no work was done on Sundays, leaving one hundred and twenty-two working-days, of eight and a half hours average duration each. This includes the time occupied in going to the shoal in the morning and returning in the evening.

During this period 45,607 cubic yards of materials were removed and deposited at the dumping-grounds, equal to about 47 yards per hour during the hours occupied in work.

The material removed, after getting below about 6 inches of crust, composed of sand and loam, is nearly pure sand. The capacity of the steamer, therefore, working in such materials, is about 100,000 cubic yards per year. The cost is less than 20 cents per cubic yard, as shown by the following analysis:

The least cost during any one day was 19½ cents per cubic yard.
The least cost during any one week was 13 cents per cubic yard.
The least cost during any one month was 15 cents per cubic yard.
The average cost for the entire period, 5½ months, was $19\frac{4}{10}$ cents per cubic yard.

The foregoing figures cover all expenses for superintendence, wages, fuel, &c., as in the case of the St. John's River Bar. The cost could be reduced at least 20 per cent. to 25 per cent. if favorable arrangements could be made for purchasing wood delivered at the Fort Pulaski wharf. At present, the steamer is obliged to use coal, a much more expensive fuel than wood, and has to go to Savannah for it, thereby causing considerable additional expense.

From August 20, 1873, to June 30, 1874, ten and one-third months, the expenses of the steamer have been as follows:

Cost of steamer	$26,000 00	
Alteration and repairs and expenses of delivering vessel at Savannah	1,439 53	
		$27,439 53
Running expenses:		
Superintendent and crew	8,886 66	
Fuel	3,911 61	
Engineers' and steamers' supplies and repair of vessel	596 17	
Engineers' supplies and repair of pump-machinery	901 35	
		14,295 79
Total		41,735 32
Cost of vessel 10⅓ months under contract		30,380 00
Cost of vessel 10⅓ months under Government ownership		14,295 79
Amount saved to the United States in 10⅓ months by present arrangement		16,084 21

The cost to the United States since the purchase of the steamer, as compared with the cost under the contract, is shown to be over $16,000 less, or a monthly saving of about $1,560. At the same rate the entire cost of the steamer will be saved to the Government in nine months from July 1, as below:

Original cost of steamer	$26,000 00
Add ordinary wear and tear 19⅓ months, at 10 per cent. per annum	4,200 00
Total	30,200 00
Average monthly saving, $1,560 per month, 19⅓ months	30,160 00

Calculating the cost of the dredging done by the Burden on the Savannah River at 75 cents per yard, the lowest bid ever received after advertising for proposals, and the price paid the city of Savannah, and the cost of dredging on the St. John's River at the rate paid when under charter, it may be said that the vessel has already more than paid for herself.

Cost of dredging Savannah River, 45,607 yards, at 75 cents per yard	$34,205 25
Cost of dredging on St. John's River under charter	10,000 00
	44,205 25
Total cost of steamer to June 30, 1874	41,735 52

Very respectfully, your obedient servant,

Q. A. GILLMORE,
Lieutenant-Colonel of Engineers,
Brevet Major-General, U. S. A.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

APPENDIX U.

ANNUAL REPORT OF MAJOR WM. P. CRAIGHILL, CORPS OF ENGINEERS, FOR THE FISCAL YEAR ENDING JUNE 30, 1874.

UNITED STATES ENGINEER OFFICE,
Baltimore, Md., August 11, 1874.

GENERAL: I have the honor to transmit herewith the annual report for the year ending June 30, 1874, for works of improvement of rivers and harbors, and of examinations and surveys therefor, which have been in my charge.

As far as possible the usual commercial statistics have been obtained. Where they are not appended they have not been supplied by the proper officials, although in all cases they have been asked for.

Very respectfully, your obedient servant,

WM. P. CRAIGHILL,
Major of Engineers, U. S. A.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

U 1.

IMPROVEMENT OF THE SUSQUEHANNA RIVER NEAR HAVRE DE GRACE, MARYLAND.

The old wooden deflector has continued to stand as well as could be expected, and, according to the testimony of persons navigating the river, has been fulfilling its object of concentrating the flow of the water below the bridge and maintaining a better depth in the channel over the shoals below Havre de Grace.

It has not been possible, for want of funds, to make a survey of the locality.

The deflector was seriously injured and breached, by the extraordinary ice-gorge of March, 1873. A small amount of money, as much as was available, has been expended in closing the breach, as far as practicable, by sinking old hulks, (canal-boats,) twelve in number, filled with stone. This expedient, which has proved successful, has been found cheap, owing to the nearness of the canal debouching near that point, as well as of the quarries at Port Deposit.

It is believed there can be no reasonable doubt of the advantageous influence of the work already built there, and the opinion is still held that it should be replaced by a permanent structure which might be built for $50,000.

The improvement is in the collection-district of Baltimore, which is the nearest port of entry. It extends from opposite Point Concord light to Spesutie Island. The trade between Baltimore, Philadelphia, and New York, with the valley of the Susquehanna to near its head, is greatly interested in this work. The amount of this trade is large but cannot be accurately ascertained.

Amount required for the fiscal year ending June 30, 1876, $50,000.

U 2.

IMPROVEMENT OF NORTHEAST RIVER, MARYLAND.

Nothing has been done at this place since April, 1873, when Morris & *Cumings* completed their dredging. The results of their operations

were the following: a channel 60 feet wide at bottom, with a ruling depth of 5 feet at mean low-water, leading from the 5-foot curve in the Northeast River, to the wharf at Northeast; a basin about 120 feet long and 120 feet wide in front of the wharf; and a channel 25 feet wide and 3 feet deep at low-water, leading from the wharf to Alexander's mill.

A special report was made May 28, 1873, accompanied by a sketch, which showed the condition of the channels at that time. No money has been since available for an examination of the channels. The effect of the improvement has been to increase the trade of the town and enable a steamer to run regularly between it and Baltimore, as well as sailing-vessels to aid in the trade.

Northeast is in the collection-district of Baltimore, which is also the nearest port of entry.

It was estimated this improvement would cost $10,000, the whole of which was appropriated in one sum and the work done for it. No more money is now required. It is not improbable some filling may hereafter gradually take place where Stony Run empties into the channel. In time of freshets more or less sediment will be necessarily deposited from that stream.

Financial statement.

Amount in hands of officer and subject to his check	$2 74
Amount expended during the fiscal year ending June 30, 1874	2 74

U 3.

IMPROVEMENT OF ELK RIVER BELOW ELKTON, MARYLAND.

An examination of this river was made in January, 1873, and a preliminary report, with an approximate estimate of the cost of the improvement, was submitted in reply to a call for information from the Senate Committee on Commerce, which was printed in H. R. Ex. Doc. No. 124, March 24, 1873. (See, also, pp. 77 and 815 of Report of Chief of Engineers for 1873.)

The estimates of the cost of improvement now presented are based upon a more minute survey of the locality made in October, 1873. (See pp. 4 and 63 of H. R. Ex. Doc. No. 84, 43d Congress, 1st session.)

The improvement proposed was to make, by dredging a channel of 6 feet in depth at low-water, or 8 feet at high-water, from Cedar Point to Elkton, and in the Little Elk as far as Bennett's wharf. Such a channel in both branches of the river, if 75 feet wide, will cost about $36,000; and if but 50 feet in width, $25,000. Cheap dikes will be required for regulating the banks, and to provide a place behind which to place the material dredged.

An appropriation of $5,000 was made by the act of June 23, 1874, which will be expended at the worst place, viz: near Elkton, between the first and second guts, where the bar is nearly dry at low-water. A cheap dike will be built, about 900 feet long, on the right bank of the river, opposite the mouth of the first and second guts, above and below them, at a cost, it is estimated, of about $2,000. The remainder of the small appropriation will be spent in dredging and depositing the material behind the dike. The channel can be probably made 50 feet wide. The depth will depend on the price per cubic yard at which the work can be done.

It is deemed proper to call special attention to the following quotation from the report of November 18, 1873:

Should it be decided by Congress to appropriate for this work, it is a case where true economy requires the whole amount to be available in one sum, for continuous and prompt expenditure. It would not be expedient to commence the improvement unless at least $20,000 were available.

To this it may be added that if the work is to be carried through with inadequate appropriations, the cost will unquestionably be more than the amount of the original estimate.

Elkton is situated in the collection-district of Baltimore, which is also the nearest port of entry.

Financial statement.

Amount appropriated by act approved June 23, 1874	$5,000 00
Amount available July 1, 1874	5,000 00
Amount required for the fiscal year ending June 30, 1876	20,000 00

U 4.

IMPROVEMENT OF WORTON HARBOR, MARYLAND.

Nothing was done in the year past except, in July, 1873, to drive a few guide-piles to aid in the navigation of the channel, the dredging of which was completed the previous month. A channel 100 feet wide at bottom was made, connecting the wharves in use with deep water of the creek. A basin was also excavated at the head of navigation, about 150 feet long, and of the same width.

The estimate for this improvement was $12,000, which was appropriated in one sum, and the work was finished in one season. No more money is required.

Worton Creek is in the collection-district of Baltimore, which is also the nearest port of entry.

Financial statement.

Amount in hands of officer and subject to his check	$222 85
Amount expended during the fiscal year ending June 30, 1874	222 85

U 5.

IMPROVEMENT OF QUEENSTOWN HARBOR, MARYLAND.

Nothing has been done at this place since December, 1872, when work ceased upon the exhaustion of the appropriation, and the excavation of a channel from the town to Chester River at the mouth of the creek. This channel was 100 feet wide at the bottom, and about 8 feet deep at low-water. The work is stated by those interested to have been of great value to the trade of the place.

Queenstown is in the collection-district of Baltimore, which is also the nearest port of entry.

The estimated cost of this work was $9,500; the appropriations were, March 3, 1871, $5,000; June 10, 1872, $6,000; total, $11,000.

If the whole amount of the estimate had been given in one sum, and the operations not interrupted between the expenditure of one appropriation and the grant of another, the cost would not have exceeded the estimate.

No further appropriations required.

U 6.

IMPROVEMENT OF CHESTER RIVER, AT KENT ISLAND NARROWS, MARYLAND.

A survey of this locality was made in October, 1872, and a report submitted. It was estimated that, to excavate a channel from Eastern Bay to Chester River 100 feet in width, would cost $23,000, if 7 feet deep at mean low-water.

An appropriation of $15,000 was made March 3, 1873. Some legal question having arisen as to the right of the United States, in the progress of the work, to remove a causeway, which has been standing, under the authority of the State of Maryland, for more than fifty years, across the channel separating Kent Island from the mainland, it was decided by the Secretary of War, after consulting the Attorney-General of the United States, to defer operations until the laws of the State relating to the subject should be repealed or properly modified.

By an act approved April 11, 1874, the State of Maryland assented to the removal of the causeway, but with the provision that, "before the said causeway shall be cut or opened, there shall be built a bridge," with a draw of not less than 60 feet in width. In consideration of this provision the Secretary of War decided, further, that the improvement would not be begun until the bridge was built, when the causeway could be removed and the dredging of the channel be done at the same time. The money available may thus be most advantageously and economically expended.

A further appropriation of $5,000 was contained in the act of June 23, 1874, making a total of $20,000.

To complete the estimate the sum of $3,000 is required.

This locality is in the collection-district of Baltimore, which is also the nearest port of entry.

Financial statement.

Balance in Treasury of United States July 1, 1873	$15,000
Amount appropriated by act approved June 23, 1874	5,000
Amount available July 1, 1874	20,000
Amount required for the fiscal year ending June 30, 1876	5,000

U 7.

IMPROVEMENT OF THE HARBOR OF BALTIMORE, MARYLAND.

The object of this work has been to make a channel 24 feet deep at mean low-water, for the approach of vessels drawing 22½ or 23 feet, to the city of Baltimore, at any ordinary stage of tide.

On the 30th of June, 1873, the United States contractors were engaged in the Craighill Channel and the Fort McHenry Channel, while other contractors, under the Patapsco River Improvement Board, were excavating in the Brewerton Channel—all under the supervision of the United States engineer. Operations were vigorously prosecuted in all three divisions of the channel, and by January 1, 1874, the channel was available for use. The contracts were completed about May 1, 1874. During June, 1874, a thorough resurvey of all the channels showed them to be generally in excellent condition, though still requiring additional work to bring them to completion. Attention is requested to the appended communication to the Patapsco River Improvement Board,

which contains a historical sketch of the improvement and the interesting facts connected with it.

It is obvious, as stated in previous reports, that this channel will require repairs and supervision to keep it in condition for use, as is the case with all artificial highways, such as railways, canals, or ordinary roads. This channel is nothing but a canal in the middle of a river. It has been estimated that the sum of $50,000 will be needed every year after its completion for such repairs as will be required for the constant counteraction by man of the tendency of nature to bring portions of the channels back to their normal depth, in some parts not greater than 17 feet. The necessity of properly regulating the port-warden's lines, to which previous reports have called attention, is still pressing, both within and without the limits of the city.

The interests to be affected by this improvement embrace a large area in the southern, western, and northwestern sections of the country, for which Baltimore is rapidly coming to be regarded as a great commercial center.

The estimate for this improvement was $760,000.	
Of this amount the city of Baltimore has supplied, in 1872 and 1873	$350,000
Congress has appropriated $375,000, as follows:	
June 10, 1872	100,000
March 3, 1873	200,000
June 23, 1874	75,000
Total by city and Congress	725,000

Had this whole sum been at once available, the work would have been completed for that amount. Suspension of operations from want of funds and changes of contractors necessarily make work cost more than if the operations are continuous and actively carried on throughout by the same parties. For the annual reparations needed in this improvement there should be provided $50,000. For 1873 and 1874 this sum was, in each year, necessarily taken from the funds appropriated, and so it must be in 1875; and hence, to bring the work to completion, we should have at once $150,000+$35,000, to fill the original estimate These together make $185,000. To provide still further for the repairs of 1876 we should have $50,000 more, or a total of $235,000 for the year ending June 30, 1876.

Financial statement.

Balance in Treasury of United States July 1, 1873	$200,000 00
Amount in hands of officer and subject to his check	6,913 58
Amount appropriated by act approved June 23, 1874	75,000 00
Amount expended during the fiscal year ending June 30, 1874	206,306 07
Amount available July 1, 1874	75,607 51
Amount required for the fiscal year ending June 30, 1876	235,000 00

Communication of Major Craighill to the Patapsco River Improvement Board.

BALTIMORE, MD., *June* 26, 1874.

Hon. Joshua Vansant, Mayor of Baltimore; Mr. J. W. Garrett, President Baltimore and Ohio Railroad; Mr. J. H. Pleasants, President Board of Trade; composing Patapsco River Improvement Board:

GENTLEMEN: It is my agreeable duty to announce to you, as the representatives of the interests of the city of Baltimore in the matter, the practical completion of the work undertaken for the improvement of the ship-channels connecting your city with the deep waters of the bay.

Before referring to the present condition of the work, it will be perhaps interesting

to review its past history to some extent. From its earliest settlement, Baltimore has steadily progressed in importance as a commercial entrepot until to-day, when her prospects seem more brilliant than ever before.

HISTORY OF THE IMPROVEMENT.

During the earliest period of this era of progress, owing to the moderate draught of the shipping then in use, there was no difficulty in reaching the city by the natural channels, which afforded a depth of from 16 to 18 feet at mean low-water. In course of time, as the comparative economy of transport in large vessels was apparent and admitted, it became equally evident to her citizens that if Baltimore was to retain and increase her European trade some measures must be adopted for obtaining a greater depth of water in the ship-channels.

It has not been found practicable to ascertain exactly when this subject was first agitated among the citizens, but we find that in 1852 (nearly a fourth of a century ago) a fact giving evidence of a foresight and energy which her recent action in this matter shows has not deserted her people, a "Board of Commissioners of the Patapsco River Improvement" was in existence, consisting of Messrs. Brune, Leslie, Cooper, and Brown. This board was charged with the expenditure of a special appropriation of $50,000, made by the city, together with a portion of the duties levied by the State on auction sales, not exceeding $20,000 per annum, which was, by a special law, transferred to the city for use in the improvement of the ship-channels.

About the same time (1852) an appropriation of $20,000 was made by Congress for this purpose, and Captain (now Colonel and Brevet Brigadier-General) Henry Brewerton, United States Corps of Engineers, was placed in charge of the work, with instructions to prepare and submit a project for the accomplishment of the desired ends.

The area covered by this proposed improvement naturally arranged itself in two divisions: the upper, commencing at Fort McHenry and extending one and a half miles below Fort Carroll, was six miles long, and had an average natural depth of from 19 to 21 feet at mean low-water; the lower division, extending from a point one and a half miles below Fort Carroll to the entrance buoy of the old ship-channel, about four miles beyond North Point, was nine miles in length, with an average depth of only 16 to 18 feet of water.

A comparison of the earliest and latest hydrographic surveys showed very slight changes in the general depths and condition of these channels, indicating thereby that the river, and portions of the bay adjacent to the river's mouth, had established an equilibrium between the forces of the flowing waters and the resistances of the banks and bed; and that, while the operation of natural causes would always tend to preserve and restore this condition, yet it would necessarily be very gradual in its operation, owing to the feeble currents produced by the small rise and fall of the tides, the large area of water-way, and the infrequency, if not the entire absence, of sediment-bearing freshets.

Under these conditions, it was evident that the excavation of a channel of the required dimensions was in this case the most proper and economical method of effecting the improvement.

THE BREWERTON CHANNEL.

We find accordingly that, in the autumn of 1852, Captain Brewerton recommended the formation, by dredging, of a channel 150 feet wide and 22 feet deep at mean low-water, extending in a direct line from Fort McHenry to a point one and a half miles below Fort Carroll, and thence in another straight line a distance of nine miles to the old ship-channel entrance buoy, about four and a half miles beyond North Point. He further advised, as the natural depth in the upper division was so superior to that in the lower, (being in fact nearly as great as was then thought to be required,) that all operations be concentrated in the lower division, until it was at least equal in efficiency to the upper. It may be well here to state that this recommendation was approved and rigidly adhered to, and that no work was done between Forts Carroll and McHenry until the spring of 1873.

The dimensions given above were only adopted by Captain Brewerton after consultation with the Board of Commissioners, pilots, and many others interested in the work. Much difference of opinion prevailed at that time as to the required widths and depths, but those given above were finally adopted by both the Government and city authorities as being best suited to the combination of means at command and the requirements of navigation.

As the result of a conference between Captain Brewerton and the Board of Commissioners, a joint plan of action was adopted, and from that time to this, the two parties have worked harmoniously together on this important work, generally if not always in accordance with the plans and under the general direction of the officers of the General Government who have successively had charge of the operations at different times.

At the time Captain Brewerton assumed direction of this work, the city was in possession of a dredging-machine, said to have cost $70,000, which was then operating about the wharves. The style and ultimate fate of this costly machine are involved in obscurity, but it seems never to have worked on the river improvement proper.

After an exhaustive examination of the various kinds of dredging-machines then in use, Captain Brewerton then recommended the adoption of the Osgood patent, as then constructed by Mr. A. B. Cooley, of Philadelphia, as being the best adapted to the execution of this particular work.

In accordance with this recommendation, the commissioners ordered one dredge of this gentleman in December, 1852, and another was contracted for by Captain Brewerton for the United States in the following April, 1853.

In October, 1853, operations were commenced under Captain Brewerton's supervision on the line of the new channel by the city and United States, with a force of one dredge each. Owing to the superior and nearly sufficient depth in the channel above Fort Carroll, it had been determined (as previously stated) to confine operations first to the completion of the lower division of the channel, and accordingly these dredges commenced work at the angle below Fort Carroll. Operations were continued by the two dredges until December 17, 1853. They resumed work in May, 1854, and in July a second dredge was added to the city force, the three dredges working thence until December 2, 1854.

Operations were resumed with the same force in May, 1855, and continued until January, 1856, when a cessation became necessary for repairs, work being recommenced in May following.

During this year Congress appropriated $100,000 additional, and in the fall two more dredges and a tug-boat were contracted for by Captain Brewerton, which joined the force already at work on the channel in May, 1857, making a total of five dredging-machines and two tug-boats, each dredge having four scows for the conveyance of excavated material to the dumping grounds along shore.

The dredges were removed to town for repairs, &c., in February, 1858, returning to the work in March, with a fourth dredge added to the force by the General Government. In September of this year (1858) the Government appropriation became exhausted, and operations on the part of the United States were suspended by Captain Brewerton.

One of the dredging-machines and its scows was lent to the Board of Commissioners, who continued the work on the channel during the remainder of the season of 1858, and those of 1859 and 1860. The improvement of the ship-channel ceased from this time for six years, (until 1866.)

At the time that operations ceased in 1860, the results obtained were a channel 150 feet wide, and about 22 feet deep at mean low-tide, from a point one and a half miles below Fort Carroll to a point just beyond North Point, about four and a half miles in length, and several incomplete cuts extending a mile or two below; but the whole work was left in an unfinished and incomplete condition. It is proper, also, to remark here that from the cessation of operations in 1860, until the summer of 1871, the amounts of the appropriations were so small that little more could be done than holding the depth already gained.

The original estimate for this channel was		$390,000 00
Expended to date of suspension:		
By United States	$120,000 00	
By city and State	184,317 06	
		304,317 06
Balance on original estimate		85,682 94

This division of the improvement was at this time named by the Board of Commissioners the "Brewerton" Channel, and as it has been known from that time by this name it will be so designated hereinafter.

THE CRAIGHILL CHANNEL.

No further steps were taken for the completion of this work until 1866, when the General Government having appropriated $15,200, a careful resurvey was made, under my direction, of the river and bay below Fort Carroll, which developed the fact that the action of the tides and currents coming down from the upper bay and the Susquehanna had materially injured the excavations made below North Point, and that all the lower portion of the original line eastward of Seven-Foot Knoll light was subject to obstruction by fields of ice. In consequence, a new location was made, deflecting from the Brewerton Channel three-fourths of a mile below Seven-Foot Knoll light, near the terminal point of the work completed previously, and running thence due south toward Sandy Point light. On this line a channel was projected 200 feet wide and 22 feet deep at mean low-water.

The dredges, three in number, with their complement of scows, and one tug-boat having been put in working order, commenced operations at upper end of the new cut south from the Seven-Foot Knoll, and were continued during the successive seasons of 1866, '67, '68, and '69.

In September, 1867, I was succeeded in charge of the work by Brevet Major-General Parke, major of Engineers, who carried on the work in this channel until May, 1868, when he was relieved by Brevet Brigadier-General Simpson, colonel of Engineers, who in November, 1869, announced the due south channel as open to commerce, 200 feet wide and 21 feet deep, and that the Brewerton Channel had been re-opened for a limited width to the same depth.

Here I must be permitted to refer to a matter which has been an embarrassment to me, but the explanation should be made, and perhaps no better occasion will occur. My name has been given to the new or lower channel. This was done through the courtesy and kind feeling of my friend, Gen. J. H. Simpson, Corps of Engineers, without consultation with me.

In 1870, an appropriation having been made by Congress of $42,900, he dredges, tug, and scows were thoroughly repaired and set to work in the Brewerton Channel, where they continued until November.

During that month I was again placed in charge. During this winter the Government dredges and scows, being old and much worn, requiring frequent and costly repairs, were sold, and the work was thenceforth carried on by contract, with a marked increase in rapidity of execution and an equally marked decrease in cost.

Fifty thousand dollars having been appropriated by Congress in March, 1871, contracts made with Mr. Brainard, of Albany, N. Y., and Mr. Dodge, of Fulton, N. Y., for the removal of about 310,000 cubic yards of material, the former contractor commenced work in July in the Brewerton Channel, and the latter in the same channel in September following. The work also actively assisted in this season by Captain Cooper, port warden, with two dredges belonging to the city.

In the spring of 1872 Congress appropriated $100,000. The great increase in the commercial importance of Baltimore since the late civil war, and the great development of her foreign trade, especially in her steamship lines, made the pressure so great for more rapid progress than was possible by the use of the Government appropriations alone, that in the spring of this year (1872) your board was organized by the city, and $200,000 placed at your disposal for immediate application.

The availability of this additional amount of money rendered easy the execution of the work in a much more energetic and satisfactory manner than had been possible hitherto; the fact being that the very limited amounts previously devoted to it had not much more than sufficed to retain from year to year the advances already made, and to prevent the deterioration which natural and incidental causes necessarily produce.

It also rendered possible the completion of the improvement on a much larger scale than originally contemplated, and on one to render it competent to meet the requirements of to-day, which differed so greatly from those existing at the inception of the undertaking.

It had been perceived for several years previous that to make the improvement really efficient it would be necessary to increase considerably both the width and depth of the proposed channels. This had, indeed, been recommended, but no steps taken toward its actual consummation.

During this spring, however, (1872,) the whole project was revised, and the channels marked out in three divisions, of dimensions as follows: From Fort McHenry to the angle below Hawkins' Point, 250 feet wide, 24 feet deep at mean low-water; thence to angle near Seven-Foot Knoll, (Brewerton Channel,) same dimensions; thence due south toward Sandy Point, 250 feet wide, through softer portions, and 400 feet through oyster-beds and hard lumps, and 24 feet deep throughout.

Early in the summer of 1872, under existing contracts for nearly 300,000 cubic yards on the part of the General Government, and for 450,000 on the part of your board, operations were commenced on the revised project, with a total of thirteen dredges, three of them being of the clam-shell type, and forming altogether probably the largest force of dredges ever employed in this country at one time on the same improvement. The larger portion of this force was placed at work on the northern side of the old Brewerton Channel to excavate the additional width to that section of 100 feet, while three dredges were engaged on the lower portion of the Craighill Channel.

This addition to the Brewerton Channel, 100 feet wide, 24 feet deep, and six and three-quarters miles long, was completed during the year 1872, and the buoys marking the northern edge of the cut were moved over to permit the unobstructed use of the new channel, while the dredges should be engaged in deepening the old one.

During the early spring of 1873, the sum of $350,000 was made available, the General Government and the city of Baltimore contributing nearly equal portions. Contracts were entered into by your board with Messrs. Morris & Cummings for the removal of 760,000 cubic yards of material (subsequently increased to 960,000 yards,) and by the General Government with Messrs. Curtis, Tobes & Co., for the removal of

750,000 yards; there was also remaining unexecuted the major part of a contract with Mr. G. H. Ferris for the removal of 300,000 yards from the Craighill Channel. Of these amounts 835,000 yards were to be removed from the Brewerton Channel, 750,000 from the Fort McHenry Channel and 375,000 from the Craighill Channel. The main portion of this work was executed during 1873, the contractors suspending work a short time during the winter for repairs, and finally completing their contracts during April, 1874.

We have thus traced this work through its various stages of progress to what may certainly, in a measure, be termed its completion.

HOW THE WORK WAS DONE.

The marked incidents connected with the last two years of its progress are the decline in cost of dredging and the increase in rapidity of execution. It is not too much to say that with the machines heretofore used in this work, and at their usual average of daily work, it would have required from five to eight years to accomplish the same results. From the 10th of April, 1873, to the 10th of April, 1874, seven dredges of the clam-shell type excavated and removed an average of 900 yards each per day for each calendar day, including sunshine and storms, Sundays, holidays, and delays, and stoppages of all kinds. Their execution during actual working days at times reached over 3,000 yards per day. The greatness of this advance will be perceived when it is considered that a *very good* average under similar circumstances for the dredges heretofore employed would be 250 yards per day—their *maximum* capacity being from 600 to 700 yards per day.

At the same time the price per cubic yard for this work has been reduced from 37 cents in 1871 to 22 cents in 1873.

One of the chief difficulties of the work has been, in so broad an expanse of water as is presented by the Lower Patapsco and the Bay, to keep the dredges in place in the excavation of a narrow channel.

LOCATION OF THE CHANNELS.

It may therefore be relevant to present a brief outline of the methods used for determining the proper locations for these channels, for securing the accuracy of their alignment during the execution of the work, as well as the proper execution itself.

In the first place, general surveys were made to determine the best location for the channels as to depths, &c. These results being plotted, the lines were laid down on the map, and their positions determined with reference to certain established points on shore. With these data, and from these fixed stations, points in the selected lines for the channel were accurately determined by triangulation, and marked by wooden piles driven into the bottom of the river or bay. These points being for each channel on the same side, formed continuous rows, the slightest irregularity in which would exhibit itself to the most casual observer. The next step was to determine the depth of water within these limits more specifically and fully than the general survey would permit. For this purpose another survey was made, confined entirely to the limits of the channels as laid down, the state of the tides being noted continuously at regular intervals of time, at stations along the routes.

Being thus prepared for work, the dredges were brought into the channels and their positions fixed laterally by measurement with cords and wires from the lines of piles before referred to, their movements forward or backward being regulated and accurately measured by means of the line extending astern to an anchor fixed in the bottom. Each dredge had in its vicinity a tide-gauge to regulate the depth of cutting, and an inspector whose duty it was to see the dredge properly located, to determine the depth to which the bucket should descend, to regulate the alignments and progression of the dredge, and to see that the scows were fully loaded, as well as to record their number and contents.

CONCLUDING REMARKS.

The work as now submitted to your inspection has had for its object the accomplishment of the following result: *To permit the approach to Baltimore at mean low-water of vessels drawing from 22½ to 23 feet, and at ordinary high-water of vessels drawing 24 or 24½ feet.* This is attained by the completion of this channel with a depth of 24 feet at mean low-water.

A width of 250 feet has been given where the material on the edges is not of sufficient hardness to injure a vessel touching it. This is the case throughout from Fort McHenry down through the Brewerton Channel and about two miles in length of the lower channel. This, however, is regarded as a *minimum* width, as the sides are likely to be occasionally struck by large vessels, especially steamers, whose lengths are greater than the width of the channel, and which may not be kept exactly in the line of the channel. Where the sides are thus struck masses of material are thrown into the channel.

In some parts of the lower section of the channel, where the harder material of the oyster-banks or lumps was found to some extent, the width has been made 400 feet, to

diminish the probabilities of vessels touching the sides; in fact, to remove all danger of such striking, if due care is exercised by navigators. In some portions of the lower channel there was provided by nature herself a much greater width than 400 feet, and a much greater depth than 24 feet. Of course, in such parts no dredging has been necessary. At the turn from the Brewerton to the lower channel, which is an angle of about 90°, the width of the channel has been made about 1,000 feet, to give ample room for long vessels in passing that point. In a small portion of the lower channel the material of the bottom is so very soft that while the surface of this fluid-mud is only 22½ or 23 feet below the surface of the water at low-water, it appears no real obstacle to the passage through it of the keel of a vessel drawing 23 feet at the same stage of the tide. The last survey reveals the existence of a few very small areas where a little deepening is still necessary.

It is not to be forgotten that this channel is an *artificial* road or highway, of the same general character in that respect as a railway, or canal, or ordinary wagon-road. It did not exist by nature. It was *made*, and to be kept in good condition *it requires care in its use and annual repairs.*

Range lights and buoys have been provided to enable careful navigators to find this highway and to keep in it safely as well by night as by day. The sum which will be required annually to keep this highway in its present condition need not exceed, and will be probably less than $50,000, but it should be *regularly provided and judiciously and economically applied.*

The constant and careful use of the channel by heavy ships, and especially by screw-steamers, will improve its depth, rather than injure it. The sum of $75,000 has just been provided by Congress for this improvement.

The result now reached in the creation of this artificial highway has been attained only by the patient and persistent and combined labor, through many years, of many persons on the water and in the office. Let each receive his due share of credit. Much of this labor has been performed under my supervision, and I desire to say, emphatically, that, if this work is of any value to the great city of Baltimore, she owes more for it to Mr. N. H. Hutton than to any other person. I feel under great personal obligation to him, while assisting me in the performance of my duty, for the exhibition of much energy, patience, and skill by him, and it is but his due for me to say so in this connection. He has had the immediate charge of the operations.

In conclusion I beg to express my sincere thanks to the members of your board for the confidence manifested and the support at all times given to me during my connection with the work.

Very respectfully, your obedient servant,

WM. P. CRAIGHILL.

At the conclusion of the reading the mayor said:

"It would be an act of supererogation on my part to make any remarks on this occasion after the report just read. We have all reason to be gratified. Baltimoreans have long been aware of the necessity of these improvements. In former times 15 or 18 feet of water was sufficient for the ships then constructed, but, as these increased in size, wisdom demonstrated the necessity of beginning the work and pushing it forward. When I was a boy vessels of 400 or 500 tons were usual, and the Girard vessels of 600 or 700 tons were considered very large. The water here was then sufficient.

"It is a pleasant condition of the public mind that it is always prepared to lend its aid to improvements when made apparent. The merchants of Baltimore, to whom honor is due, kept this improvement constantly in mind. The State Commission, a member of which I see here, (R. R. Kirkland, esq.,) and others, worked assiduously, and effecting as much as possible with the small amount of $20,000 from auction-duties. With the great extension of trade it was apparent that Baltimore was to be a great entrepot, the great storehouse of products not only from the surface but below the surface.

"I need not refer to the Bremen line or the Allan line, whose presence required the construction of this channel, and, if they increase in size, of still further extending the work. The Government has liberally responded to the action of Baltimore City regarding this work, and credit is due to Mr. Swan, Mr. Albert, Mr. O'Brien, and others, assisted by the merchants, for the liberal manner in which the Government has aided the work. I bear testimony to the faithful manner in which the work has been conducted by Colonel Craighill. It was done with promptness and regularity.

"The soundings will demonstrate the work has been well executed. It has been done economically and expeditiously, and the estimates made by Colonel Craighill were found to be almost mathematically correct. Of the money appropriated by the city $50,400 remains unexpended. I congratulate you, my fellow-citizens, on the completion of the work. The channel is as a road and highway, and must be kept in its present condition. It is important for the interest of our great city, as we must have the road with which to export our grain and other articles, and to bring to this shore those articles of which we have need."

U 8.

IMPROVEMENT OF CAMBRIDGE HARBOR, MARYLAND.

On the 30th of June, 1873, Mr. Dodge, the contractor, was engaged in dredging at this place. By his operations the entrance to the inner basin was widened to 125 feet, and the sharp curve at the turn into the outer channel was eased by cutting off the projecting point on the convex side.

Work was suspended August 11, when the appropriation was exhausted. The value of the improvement may be inferred from the attached letter of the president of the Dorchester and Delaware Railroad Company, of which road Cambridge is one of the termini. The additional cut to which he refers was not contemplated by the original estimate, which was for a minimum improvement. It would, undoubtedly, be advantageous.

DORCHESTER AND DELAWARE RAILROAD COMPANY,
President's Office, Cambridge, Md., July 3, 1874.

DEAR SIR: It affords me pleasure to give you the desired information about the channel at Cambridge which you so successfully cleared out. It stands well, filling up very little if any. Another cut, widening it, would be a great improvement, and we then should have one of the prettiest little harbors in the world. For this purpose, I intend to ask an appropriation of $5,000 at the next session of Congress, which I have some assurance I can get. Since I last wrote to you a number of large vessels have loaded with lumber in 50 or 60 yards of my office for New York, Maine, and other markets. I and other citizens of Cambridge and Dorchester County feel very grateful to you and the member of Congress for this public improvement.

Most truly, yours, &c.,

W. WILSON BYRN.

Col. WM. P. CRAIGHILL,
Corps of Engineers, U. S. A.

This place is situated in the collection-district of Baltimore, which is the nearest port of entry.

The estimate of this improvement was $21,600 for a channel and basin of 8 feet depth, and $36,000 for a depth of 10 feet at low-water. Congress appropriated $10,000 March 3, 1871, $10,000 June 10, 1872, and $5,000 March 3, 1873. Total $25,000.

If the whole of the estimate, $21,600, had been appropriated in one sum, the work which cost $25,000 would have been done for $21,600. No further appropriation is asked unless Congress should feel inclined to make the addition to the channel asked for by Mr. Byrn and referred to above.

Financial statement.

Balance in Treasury of United States July 1, 1873	$5,000 00
Amount expended during fiscal year ending June 30, 1874	4,874 11

U 9.

IMPROVEMENT OF THE WICOMICO RIVER, NEAR SALISBURY, MARYLAND.

A survey of a portion of this river was made in 1871, and a report submitted. It was found that the improvement needed was the opening of a channel by dredging from the existing 7 feet water to the bridge, about 75 feet in width and 7 feet in depth at mean low-water, at a cost of about $20,000. The inhabitants offered and agreed to construct such bulk-heads as might be necessary to receive the material excavated from the river, and give proper banks to the stream, which it was altogether

proper they should do, as they would thereby be greatly improving their own property.

Congress appropriated $5,000 June 10, 1872, which was expended in 1872 in making a channel of reduced dimensions, the width being about 25 feet. The channel thus excavated was in length about four-fifths of a mile, extending from the bridge at Salisbury through the shoalest part of the river. About one-fifth of a mile of this channel had a depth of 5 feet at mean low-water; the remainder a depth of 7 feet. This was in itself a valuable improvement. The dikes, however, were not built when the dredging began, and it was promised they should be placed as soon as the dredging was completed, before the ice of winter and the freshets of spring should have degraded the banks of dredged material. The consequence (as developed by a survey made in March, 1873) was what might have been expected—a considerable filling of the dredged channel, due in great part to the causes mentioned above.

A new appropriation of $5,000 was made March 3, 1873. The understanding with which the appropriations were made being that the community interested were to construct the necessary bulk-heads, it has been thought proper to defer further attempts at improvement until these structures shall have been placed. There is now a fair prospect of their being shortly built.

An additional appropriation of $5,000 was made by the act of June 23, 1874.

Salisbury is a very thriving town, extensively engaged in the lumber-trade, and will doubtless be greatly benefited by the improvement proposed.

The Wicomico is in the collection-district of Baltimore, which is also the nearest port of entry.

This channel should receive annual repairs to keep it in proper condition. For that purpose the sum of $2,500 should be provided.

The original estimate was for completion, $17,000, which was based upon the expectation of continuous and rapid work. The appropriations have been $5,000, June 10, 1872, expended; and $5,000 June 23, 1873, now available. To complete the estimate, and provide for filling four years, the two sums of $7,000 and $10,000 are required to carry the work through 1876, or a total of $17,000.

Financial statement.

Balance in Treasury of United States July 1, 1873	$5,000 00
Amount in hands of officer and subject to his check	98 14
Amount appropriated by act approved June 23, 1874	5,000 00
Amount expended during the fiscal year ending June 30, 1874	290 35
Amount available July 1, 1874	9,807 79
Amount required for the fiscal year ending June 30, 1876	17,060 00

U 10.

IMPROVEMENT OF THE HARBORS OF WASHINGTON AND GEORGETOWN, D. C.

Under the act of Congress approved March 5, 1872, a board of survey was created for the purpose of reporting to Congress a full and comprehensive plan of improvement. This report was printed in Mis. Doc. No. 15, Senate, 42d Congress, 3d session.

An appropriation of $50,000 was made by act of March 3, 1873. The freshets of the spring of 1873 having caused considerable deposition in

the channels leading to Washington and Georgetown, an examination of them became necessary, in order to ascertain the extent of the changes reported. This examination was made by Lieutenant Thomas Turtle, Corps of Engineers, as soon as practicable after the subsidence of the freshets. A project of expenditure was submitted, the main idea of which was to expend the appropriation so as to relieve at once, as far as possible, the wants of commerce, while conforming to the plan of improvement recommended by the board of survey already referred to.

It was decided by the Chief of Engineers, in carrying out that idea, to devote $35,000 to dredging in the Virginia Channel (which is proposed ultimately to be the only channel) to a depth of 14 feet at low-water, and to expend the remaining $15,000 in dredging along the present Washington front, as high as Seventh street, to a depth of 12 feet at low-water.

Proposals for the work were received August 11, 1873, and an abstract of them forwarded to the Chief of Engineers August 11, 1873.

Up to the close of the fiscal year no authority had been given for proceeding with the work.

The board of survey recommend that, if it shall be decided by Congress to carry out their plan of improvement, not less than $2,000,000 should be appropriated for the first year. In any event, not less than $50,000 should be provided for the year ending June 30, 1876, to pay for necessary dredging to keep the channels open and to remove certain dangerous rocks in the harbor of Georgetown.

Financial statement.

Balance in Treasury of United States July 1, 1873	$50,000 00
Deduct amount expended in fiscal year 1872–'73	730 29
Amount expended during the fiscal year ending June 30, 1874	508 76
Amount available July 1, 1874	48,760 95
Amount required for the fiscal year ending June 30, 1876	2,000,000 00

Commercial statistics.

CUSTOM-HOUSE,
District and Port of Georgetown, D. C., September 17, 1874.

SIR: Yours of the 14th of July, 1874, requesting certain information to be embodied in your next report to Congress of the further improvement of the Potomac River below Georgetown, D. C., was received in due time, and, in reply thereto, would state—

First. That the amount of revenue collected at this port for the fiscal year ending June 30, 1874, was $6,956.70.

Second. In regard to commerce and navigation that would be benefited by the further improvement of the Potomac, I can give you but a partial statement, it being much more than a casual observer would suppose, who did not make investigations in regard thereto.

Steam and sailing vessels entered and cleared during the fiscal year ending June 30, 1874, viz:

379	steamers, aggregating	204,162 tons.
156	sail, aggregating	26,410 tons.
Total... 535		230,572 tons.

Belonging to the district of Georgetown—

25	steam-vessels, aggregating	3,877 tons.
80	sail-vessels, aggregating	2,058 tons.
Total... 105		5,935 tons.

Also, 372 canal-boats and barges, aggregating 22,394 tons.

Steamers engaged in the coasting trade: 3 from Georgetown to Baltimore, aggregating 2,040 tons; 2 from Georgetown to Philadelphia, aggregating 489 tons; 2 from Georgetown to New York, aggregating 666 tons; 1 from Georgetown to Norfolk, aggregating 717 tons; 1 from Washington to mouth of Potomac, aggregating 352 tons; 1 from Washington to Quantico, Va., aggregating 490 tons.

Seven of the above steamers arrive and depart once each week; two arrive and depart twice each week; one arrives and departs daily. Ten steam-tugs, the greater number of which are in constant employ.

From information received from the agents of the coal companies located here, I would state that the shipments of coal from Georgetown for the year ending June 30, 1874, was not less than 690,000 tons, which, at $4 per ton, would amount to $2,760,000, and to carry which at least 600 vessels have been employed, and, in addition thereto, about 100 vessels were partly laden here, and obliged to go below to Alexandria to complete their cargoes, because of there not being water in our channel of sufficient depth to enable them to carry full cargoes.

I am also informed that all the vessels which are now being built for carriage of coal are of the tonnage which will either necessitate the deepening of the channel, or to abandon Georgetown as a place of shipment altogether.

Grain and lumber are brought here from various sections of the country in large quantities, with other articles of commerce, in which trade quite a number of sail-vessels are employed.

All vessels arriving and departing are not under the necessity of entering or clearing, but I think I am under the number when I say that twelve hundred steam and sail vessels have arrived and departed during the fiscal year ending June 30, 1874, not numbering the small crafts, such as oyster and fishing vessels.

Third. Alexandria, Va., is a port of entry below Georgetown, D. C.

Fourth. Washington, D. C., is a port of delivery only, Georgetown being the only port of entry.

I regret very much that I cannot give you a full and complete statement of the value of the commerce of the port, but in concluding would say that great necessity exists at the present time for the improvement of the channel leading to Georgetown; in order to accommodate and facilitate its commerce, the channel should be kept free and of proper depth, that vessels of large tonnage may come and go without delay or detriment.

Very respectfully, your obedient servant,

CHAS. S. ENGLISH,
Collector.

WM. P. CRAIGHILL,
Major of Engineers.

Bids opened at 12.5 o'clock p. m., August 11, 1873.

No.	Name.	Address.	Number and kind of machines.	Average daily amount of work expected.	Place of deposit.	Time.		Price per cubic yard.	Remarks.
						Begin.	Completion.		
1	C. C. Barker	Fayetteville, N. Y.	Two Osgood dredges with tug and scows.	1,400 cubic yards.	Deep water below Alexandria.	Sept. 1, 1873	Mar. 1, 1873	$0 35	
2	Thomas P. Morgan	Washington	Two Osgood machines.	800 cubic yards		Sept. 1, 1873	May 1, 1873	0 32	Time of completion probably intended for 1874.
3	T. B. Colton	Philadelphia	Two Osgood machines.	700 cubic yards		Sept. 1, 1873	June 30, 1874	0 41	
4	A. A. Dodge	Baltimore	Three Osgood and Cooley machines.	1,000 or more	Deep water below Alexandria.	Sept. 1, 1873	Aug. 1, 1874	0 23	
					On flats or near edge of channel.			0 30	
5	G. H. Ferris	Brooklyn	One dipper machine in September and two more in spring.	500 cubic yards each machine.	Deep water below Alexandria.	Sept. 20, 1873	Sept. 1, 1874	0 22½	
6	Curtis, Fobes & Co.	Baltimore	One or more clam-shell dredges.	2,000 cubic yards each.	At or below Alexandria or such other location as they may select, satisfactory to engineer in charge.	Apr. 1, 1874	July 1, 1874	0 25	
					On flats			0 45	
7	Lewis Wolfley	Washington	McClean machine	750 to 1,000 cubic yards.	At any point not to exceed 3,000 feet from site of work showing 2 feet water at low-tide.	Oct. 1, 1873	Feb. 1, 1874	0 40	

U 11.

IMPROVEMENT OF ACCOTINK CREEK, VIRGINIA.

Under a contract dated September 14, 1872, operations were begun at this place October, 1872, and finished April 3, 1873. A channel about 40 feet wide at bottom, and from 2½ to 3 feet deep at low-water, leading from the 2½ feet water in Accotink Bay to a point about 200 yards within the mouth proper of Accotink Creek, and a channel about 4 feet deep and 25 feet wide from that point to the village, were completed. No re-examination of this creek has been made for a year, for want of funds, but it is understood that the work stands quite well, and that those interested have been planting willows on the banks to prevent their degradation.

Accotink is in the collection-district of Alexandria, which is the nearest port of entry.

Financial statement.

Amount in hands of officer, and subject to his check	$23 04
Amount expended during the fiscal year ending June 30, 1874	23 04
Amount required for the fiscal year ending June 30, 1876	14,000 00

U 12.

IMPROVEMENT OF OCCOQUAN CREEK, VIRGINIA.

At the close of the last fiscal year, Mr. A. A. Dodge was engaged in dredging a channel through "Lower Mud" under his contract, dated May 17, 1873. Operations were suspended August 12, after completing two cuts. A channel about 50 feet wide and 5 feet deep at mean low-water through the entire width of "Lower Mud," was the result of the season's work.

A re-examination of the excavated channel was made in June, 1874, demonstrating the fact that very little filling had taken place during the time which had elapsed since the cessation of work.

There were no proposals received during the year.

Occoquan is located in the collection-district of Alexandria, which is the nearest port of entry.

The original estimate for the improvement of this creek, giving a channel 100 feet wide and 5 feet deep at mean low-water, amounted to $18,000. An appropriation was made March 3, 1873, of $5,000. An appropriation was made June 23, 1874, of $5,000. Required to complete the work, $8,000.

Financial statement.

Balance in Treasury of United States July 1, 1873	$5,000 00
Deduct amount expended in fiscal year 1872-'73	1,870 82
Amount appropriated by act approved June 23, 1874	5,000 00
Amount expended during the fiscal year ending June 30, 1874	2,019 29
Amount available July 1, 1874	6,109 89
Amount required for the fiscal year ending June 30, 1876	8,000 00

U 13.

IMPROVEMENT OF THE RAPPAHANNOCK RIVER BELOW FREDERICKSBURG, VIRGINIA.

Under a contract dated August 14, 1873, Mr. A. A. Dodge removed about 17,500 cubic yards of material from the Fredericksburg Bar, de-

positing behind the dikes on either bank of the river until the space seemed full, and then carrying the remainder down the river and dumping it in places where there was little probability of its returning into the channel. This method of disposing of material is, however, radically wrong, and should never be resorted to except from absolute necessity, or to save expense when funds are inadequately provided, and a certain result must be attained. Mr. Dodge also took out some logs and snags below Spottswood Bar. His work was concluded in November, 1873. A survey made in November and December, 1873, showed the river was in a better condition for navigation than it had been for many years before. The object of the operations since 1870 had been fully attained, viz, to give 8 feet at low-water as high up as Fredericksburg, whereas previously (since the war) only 4½ feet was found at more than one place.

My opinion as to the extent of the operations required for this river was expressed in a letter to the Chief of Engineers dated April 29, 1873. As the same opinion is still entertained, a quotation from that letter is here introduced:

The estimate of about $85,000 for the improvement of the river, contained in my report of January 26, 1871, contemplated the procurement of a depth of 10 feet at mean low-water as high as Fredericksburg. The first and second appropriations thereafter having been small and inadequate to giving that depth, it was considered better to attain first a depth of 8 feet at low-water, and afterward, if the wants of commerce should require a greater depth, it could be given if the money should be appropriated by Congress. With the information now in my possession, I am of the opinion that 8 feet at low-water is sufficient for the present needs of the commerce upon the river, and I have failed, notwithstanding the manifest improvement in the navigation, to perceive any such tendency to a corresponding revival of trade on the river, or in the towns on its banks, as would justify the expenditure of any money in making a 10-foot navigation where it does not now exist.

I submit, however, an estimate below for giving *now* 10 feet at low-water as high as Fredericksburg:

ESTIMATE TO COMPLETE IMPROVEMENT—CHANNEL 100 FEET BY 10 FEET AT MEAN LOW-WATER.

Excavation.

Fredericksburg Bar, 40,000 yards, at 33 cents	$13,200
Spottswood Bar, 20,000 yards, at 25 cents	5,000
	18,200
Remainder of river, as per estimate of 1871, from Spottswood down	29,250
For contingencies, 20 per cent. of $47,450	9,490
Total required	56,940

Experience gained since 1871 indicates that it will require annually from $5,000 to $8,000 to keep the river open. It also shows that with the wrecks as they are at Spottswood Bar, (one having been removed in 1872,) no other deflector or training-dike is needed. The cut keeps well open, and only needs widening.

The appropriations by Congress since the estimate of 1871 (of $85,000 for 10 feet water) have been the following:

Fifteen thousand dollars March 3, 1871; $15,000 June 10, 1872; $15,000 March 3, 1873; $7,000 June 23, 1874; total, $52,000. To complete the estimate $33,000 are required, which would have done the work had the whole sum been at once appropriated and operations not interrupted. The work would now require $57,000 minus the $13,000 now available, or $44,000.

About $7,500 per annum will be required for this river to keep it in its present condition of an 8 foot low-water navigation, or to keep it at

10 feet, if that depth were once attained. If the whole amount of $44,000 cannot be appropriated in one sum, (and Congress is certainly the judge whether the present or prospective commerce of the river would require a corresponding navigation of 10 feet,) the true policy is to appropriate not more than $7,500, the annual sum. Five thousand dollars would probably be sufficient for the year ending June 30, 1876.

This work is located in the collection-district of Tappahannock.

The report and estimate of 1871, having been omitted from the annual report of 1871, is hereto appended as a part of the history of the improvement of the river.

A letter from the collector of customs at Tappahannock, Va., dated August 10, 1874, is also appended hereto.

Financial statement.

Balance in Treasury of United States July 1, 1873	$15,000 00
Deduct amount expended in fiscal year 1872–'73	1,913 92
Amount appropriated by act approved June 23, 1874	7,000 00
Amount expended during the fiscal year ending June 30, 1874	7,107 19
Amount available July 1, 1874	12,978 89
Amount required for the fiscal year ending June 30, 1876	7,500 00

Bids opened at 1 o'clock p. m., July 25, 1873.

No.	Name.	Address.	Time.		Price per cubic yard.
			Begin.	Complete.	
1	G. H. Ferris	Brooklyn	Oct. 1, 1873	Jan. 1, 1874	$0 39
2	A. A. Dodge	Baltimore	Sept. 1, 1873	Jan. 10, 1874	33

Contract to A. A. Dodge, at 33 cents per cubic yard.

Report and estimate of 1871.

UNITED STATES ENGINEER OFFICE,
Baltimore, Md., January 26, 1871.

GENERAL: I have the honor to submit herewith a report and estimates on the subject of the improvement of the Rappahannock River, Virginia, a duty devolved upon me by Engineer Department letter of July 23, 1870.

The necessity for some effort toward the amelioration of the condition of this river was recognized by the General Government at least as early as 1852, at which time the late General Mansfield (then captain Corps of Engineers and brevet lieutenant-colonel) was directed to make an examination and report. Owing to the want of a detailed survey and map of the river, his report at that time was only general and preliminary in its character, and resulted in the suggestion that $40,000 be appropriated for commencing operations on the improvement, pending the execution of a thorough survey of the river from Fredericksburg to the bay, when a final report and estimate might be made. This survey was made by the United States Coast Survey, at General Mansfield's request, during 1853 and 1854, but no further action was had on the question of the

river improvement from that time until now, so far as my knowledge goes.

The survey of 1853–'54 materially abridged the amount of field-work required at this time to enable me to report intelligently on the kind and amount of work necessary to be done to effect the desired improvement. The general results of the examinations made in 1870 under my direction indicate no material change in the condition of the river since the date of General Mansfield's report. The extent and character of the obstructions are generally the same, consisting of bars or shoals, formed either in those places where the river, having a straight course, expands in width suddenly, or near the mouth of tributary streams. The depth of water over the principal of these bars was found to be nearly as given by General Mansfield, though differing considerably from those given by the Coast Survey map. Fredericksburg, which is the commercial center of the interests involved in the improvement of the Rappahannock, is situated on the right bank of that stream, about 160 miles above its junction with Chesapeake Bay. It had, for a long period anterior to the late war, maintained a very considerable coastwise and European trade, and, despite the impediments to a free navigation of the river, was rapidly increasing in wealth and importance.

Its annual coastwise shipment of grain formerly exceeded 1,000,000 bushels, and its flour and woolen goods possessed an extended European reputation.

So long as ninety years ago vessels loaded at Fredericksburg directly for ports in Europe; since 1820, however, the shoaling of the river has entirely cut them off from that trade. The water-power of this point is said to equal that of Lowell, Massachusetts, both in power and availability. By means of damming, this power has been put in condition for immediate use, and, indeed, is now quite extensively utilized, though it needs capital and a more certain navigation to the bay to develop its full capacity. It is believed that when the means of sure and cheap transit thence by the river is assured capital will offer in abundance to do the rest. That the wealth and prosperity of this section will be increased by this improvement, and consequently that of the whole country, there can be no doubt.

The river, from Fredericksburg to Port Royal, (about thirty miles below,) winds in a tortuous course between banks generally well elevated and stable, though showing at some points indications of sliding, which would probably be remedied by removing the superincumbent timber. Its width, between these points, gradually increases from 350 feet to 1,500 feet; though presenting several enlargements beyond this ratio, where are generally found the obstructing bars and shoals. Below Port Royal the river expands gradually, until at its mouth it has a width of four miles. The bottom is generally sandy, and the current without sufficient force to preserve a stable channel.

As far as a discussion of the river improvement is concerned, Port Royal may be considered the mouth; beyond that it is an arm of the bay. The influences of freshets and fluvial currents are lost beyond this, and all of its characteristics are those of an estuary rather than a river. On this lower portion of the river only two obstructions exist to navigation, viz, at Nanzatico and Naylor's Hole. The first (caused by a sudden enlargement of the water-way) is slight in extent; the latter is caused by the confluence of two opposite tides, occurring at a point naturally inclined to shoal, and it will be probably removed to a point lower down and more favorable by any improvement which facilitates the tidal movement in the upper river. The river, then, requiring im-

provement, may be called thirty miles in length. The obstructions are bars and shoals formed either by enlargement of the water-way beyond its low-water capacity to fill properly, or to enable the channel to maintain its own stability; or are the effect of tributaries arresting the floods at the mouths, and forming bars.

The wrecks deposited in the river during the war, though undoubted obstructions, are small in size and insignificant in numbers.

It is proposed to remove the bars and shoals by dredging; to form a channel 100 by 10 feet at mean low-water; to break up and remove the wrecks by blasting, and in some cases to assist the channel in preserving its proper position and depth by the use of dikes or jetties of cheap construction.

It is believed that a general system of training-dikes, which would regulate the size of water-way in accordance with its volume and the required depth, assist the upward movement of the tidal wave by diminishing friction along the banks, and control and assist the ebb, would prove highly beneficial. As their proper construction would prove expensive, and as much if not all that is at present required can be done without their use, except in special cases, as mentioned above, they have not been included in the plans and estimates herewith submitted.

The estimated cost of a channel 100 feet wide and 10 feet deep, at mean low-water, is $83,760, and I would recommend that that amount be appropriated for this purpose.

To the report of my assistant, Mr. N. H. Hutton, which accompanies this, and his maps, I respectfully refer for details of the survey and its results.

The following papers are also transmitted herewith, viz:

1. Extract from Colonel Mansfield's report of November 26, 1852.
2. Letter of November 12, 1870, from Mr. Wentworth, collector of the district in which the Rappahannock is situated.
3. Letter of October 5, 1870, from Mr. A. K. Phillips, once custom-house officer at Fredericksburg.
4. Printed petition to Congress, detailing certain facts of importance about the Rappahannock River, and praying for an appropriation for its improvement.

To show the relative positions of the several localities, of which detailed sketches are transmitted, reference is requested to the printed Coast Survey map of the river, a copy of which is supposed to be in the Engineer Bureau.

Very respectfully, your obedient servant,

WM. P. CRAIGHILL,
Major of Engineers.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

Report of Mr. N. H. Hutton, Assistant Engineer.

UNITED STATES ENGINEER OFFICE,
Baltimore, Md., January 24, 1871.

MAJOR: In accordance with your instructions, I have the honor to submit herewith the results of an examination made under your directions of the Rappahannock River, Virginia, with a view to the improvement of its channel.

A very thorough survey of the river, in 1853, made by the United States Coast Survey, rendered unnecessary any more extended operations in the field at this time than an examination of such portions of the river as were shown on the map of that survey to have a channel-way of less depth than that desired to be obtained, in order to

determine what, if any, changes had occurred in the position and depth of the channel, and their extent and character.

The result of an interview with those citizens of Fredericksburg most largely interested in the development of commerce dependent on the river improvement, indicated that a depth of 10 feet at mean low-water would be a sufficient depth to meet all the requirements of the case. The examinations were, therefore, confined to obstructions to the use of that amount of water.

Tide-gauges were established at Fredericksburg (head of navigation and tide-water) and at Port Royal, thirty miles below, and the state of the tides recorded at every half hour from 6 a. m. to 6 p. m. during the continuance of the survey, which commenced on the 11th and was completed, in so far as the weather permitted, on the 15th of November, (both dates inclusive.)

The survey was carried on with a yawl boat; soundings were made with a graduated rod, used by one of the most experienced pilots on the river, and angles were measured by means of a prismatic compass, checked by frequent reference to established points on shore.

Commencing at Fredericksburg, the survey was carried on continuously to Port Royal. On arrival at that place, the weather, which had been hitherto extremely favorable, became so boisterous and inclement as to preclude the hope of an examination of the only two shoals below (Nanzatico Reach and Naylor's Hole) within the limits of a reasonable delay.

The Coast Survey chart has consequently been used as the basis for calculation at those points in the following estimates, and without any probable chances of error in the results, as the opinions of all those acquainted with the river coincide in the belief that those places, being beyond the influence of freshets and river-currents, have not changed in any respect since 1853 and 1854.

The obstructions to a 10-foot navigation (with the exception of a few old and dilapidated wrecks) were found to consist of bars or shoals, formed either by the sudden expansion of the water-way beyond its useful width, or by the influence of tributary streams, which, checking the downward flow of the main river in times of high water, produce, adjacent to their debouches, bars of sediment.

Freshets are of annual occurrence, sometimes attaining a height of 25 feet above mean low-water, but generally, in the opinions of those residing near the river, not exceeding from 12 to 16 feet in height. The mean rise and fall of the tides is reported as 2′ 3″. During the examination, no evidence of any excessive wash of the river-banks was observed. They are generally high and stable, though near Spottswood's Bar, and at several other places below, for short distances were formed slides, caused by the weight of timber above, which could readily be remedied by clearing the slopes for a few hundred yards back from the river.

The tributaries entering the Rappahannock between Fredericksburg and Port Roya. are few in number and unimportant in size; whatever of injurious effect they may produce on the river in times of high water, must be attributed to their action in checking the downward current of the main stream by their discharge at an obtuse angle, as their drainage areas are too limited in extent to contribute any serious amount of sediment. If it be true that this is their only injurious effect, it can be rendered innocuous by extending their entrance into the river in a direction more nearly coincident with the current of the latter.

Commencing at Fredericksburg, a shoal is found extending along the whole front of the town, and down the river as far as the mouth of Deep Run. It has a length of 1,800 yards, and from four to seven feet of water on it at present. The river-bed here presents the appearance of a general elevation or plateau throughout its whole extent, and it appears probable that a channel once excavated through it would retain its depth.

The next shoal is that known as Spottswood's Bar, four miles below town, where the river expands in width, leaving a current without sufficient force to maintain a regular channel. Its length is about 1,800 yards, and the least depth about six feet at low-water.

At Castle's Ferry, eight miles below Fredericksburg, is found the next bar, which arises from the same cause as the one above. Its length is 700 yards, and depth of water at present 8 feet.

A bar of slight extent is found at Farleyvale Reach, four miles below Castle's Ferry having a length of 350 yards, and a depth of 8 feet. In addition to the bars as named above, the wrecks of five or six small vessels obstruct the channel opposite Fredericksburg, and three are found obstructing the "cross-over" at Spottswood's Bar. They are all small, and can be easily removed by blasting.

No other obstructions to a 10-foot navigation at low-water are found above Port Royal; the next in order being at Nanzatico, three miles below that town, having a length of 800 yards, and a depth of 7 feet at present.

Naylor's Hole, thirty miles below Port Royal, and just above Tappahannock, is the next and last shoal. At that point the river has a loose, sandy bottom, and an expanded water-way, through which the channel meanders with insufficient force to preserve stability of position or depth.

The confluence of opposing tides, which also occurs here, renders a bar inevitable. It has a length of 800 yards, and a least depth of 7 feet. It is believed that any improvement which facilitates the movement of the tidal wave above this will tend to remove this bar lower down the river, and to a position where its tendency to increase will be lessened. The composition of all the shoals and bars encountered on this stream is of sand and mud, easily removable by dredging. This would seem, therefore, to be the principal work required to effect the desired improvement of the river. As most, if not all, of the bars and shoals arise from conditions of the river, indicating a greater area of water-way than the low-tide volume of the river can supply with the required depth of water, it would seem that a system of "training-dikes" could be beneficially employed, which would serve to regulate the dimensions of water-way, facilitate the movement of the flood-tide upward, and govern and direct the ebb. This system, which might be usefully applied throughout a large extent of the river, and would probably result in establishing permanently even a greater depth than 10 feet at low-water, has not been estimated for at present, as will be seen by reference to the accompanying maps, except at such points as their use seemed imperative.

As the sinuosity of the river, its narrowness and high bluff banks, which shut out and break up the prevailing winds, will render essential towing or steam transports in the navigation above Port Royal, a width of channel-way has been adopted of one hundred feet, and its estimated cost is as follows:

Channel 100 feet wide, 10 feet deep at low-water:

Fredericksburg Bar:	
87,000 yards, at 25 cents	$21,751
200 feet dike, at $2.50	500
5 wrecks, at $500 each	2,500
Total	24,750
Spottswood's Bar:	
50,000 yards, at 25 cents	12,500
600 feet dike, at $2.50	1,500
3 wrecks, at $600 each	1,800
Total	15,800
Castle's Ferry Bar:	
20,000 yards, at 25 cents	5,000
600 feet dike, at $2.50	1,500
	6,500
Farleyvale Beach:	
8,000 yards, at 25 cents	2,000
Nanzatico Reach:	
26,000 yards, at 25 cents	6,500
1,200 feet dike, at $2.50	3,000
	9,500
Naylor's Hole:	
27,000 yards, at 25 cents	6,750
1,800 feet dike, at $2.50	4,500
	11,250
Making a total cost of	69,800
Add 10 per cent. for superintendence	6,980
Add 10 per cent. for contingencies	6,980
	83,760

Accompanying this are maps of all those places where bars were found during this survey, and one or two places which were indicated as having less than 10 feet of water on the Coast Survey map of 1853-'54, but which were found to have that depth or over at the present time.

These sketches are all drawn to a scale of $\frac{1}{10000}$, except Nanzatico and Naylor's Hole, which are on a scale of $\frac{1}{5000}$. The soundings in *black* are those of Coast Survey,

made in 1853-'54. Those in *red* are the depths as measured during the recent survey. The location and extent of excavations proposed are shown in *red* outline, shaded with *blue*—the proposed dikes in *red*.

Very respectfully, your obedient servant,

N. H. HUTTON,
Civil Engineer, Assistant.

Maj. WILLIAM P. CRAIGHILL,
Corps of Engineers, U. S. A.

Extract from report of Capt. J. K. F. Mansfield, Corps of Engineers, of 1852.

WASHINGTON CITY, *November* 26, 1852.

SIR: * * * * * * * * *

I made, personally, a reconnoissance of the river, and have obtained the following information:

It appears that in 1802, and as late as 1812, ships have been loaded at the wharves at Fredericksburg, but that since that period the channel has been gradually filling up by deposits brought from above the falls, till at this time there is only 7 feet of water, at high-water, at the wharves, and about 8 feet water only can be carried at high-water over Hazel Run Bar, one mile below the city, and about the same depth for two miles beyond; thence to Spotwell's Bar, five miles farther, there is about 10 feet water at high-water; thence about eight miles farther, at Moss Neck, there is a reach of about two miles with 10 feet water at high-water; thence at Port Tobago, about ten miles below Port Royal, the channel is quite crooked, and 11 feet of water at high-water; thence at Naylor's Hole, five miles above Tappahannock, the channel very crooked and 9 to 10 feet water at high-water the whole distance to Tappahannock. The indications are generally, at different places, about 10 feet water at high-water, till Tappahannock be passed, and the bottom is represented as of sand and lumpy. The river is narrow at Fredericksburg, and continues so for miles below, widening very gradually till Port Royal is reached, say forty miles below the city, when it begins to expand rapidly, and finally attains a width of about four miles, with a tortuous channel and extensive shoals on either side, varying according to particular localities.

There is no bar, however, at its mouth as it enters the Chesapeake Bay, and it may be looked upon as an arm of this bay, extending up as far as Port Tobago, ten miles below Port Royal, and eighty miles from its mouth.

This river may be called one hundred and thirty miles long from the falls at Fredericksburg to its mouth, and it maintains a general uniform direction from the interior of the State; at Fredericksburg a canal slack-water navigation of fifty-six miles up the valley of the Rappahannock to Waterloo connecting with it, and thus it is made an important means of transpostation of about one hundred and eighty miles from Chesapeake Bay into the interior, by water, independent of the connection it has, and will have, eventually, with railroad. Its banks are generally high and present a permanent slope, and the freshets of the river, which are of short duration, probably never exceed 20 feet in height, and are but slightly felt below Port Royal.

The country throughout the whole extent of this river is in a high state of cultivation, and it is very important as one of the arteries of coastwise commerce to the extent of about $4,000,000 annually.

I have thus shown the obstacles to the navigation of this river to be simply the deposits of mud, sand, &c., washed into the channel, and the crooked channels through the broad bed of the river as it expands into an arm of the Chesapeake; and it would appear that there can be no difficulty in the way of restoring this beautiful river to its original usefulness as a highway of commerce for the whole country, and particularly to the city of Fredericksburg and Falmouth, where there are established flouring mills and cotton manufactories.

I am, very respectfully, your most obedient servant,

JOS. K. F. MANSFIELD,
Captain Corps Engineers, and Brevet Colonel.

Bvt. Brig. Gen. JAS. G. TOTTEN,
Chief of Engineers.

Commercial statistics.

CUSTOM-HOUSE, TAPPAHANNOCK, VA.,
Collector's Office, August 10, 1874.

SIR: I have the honor, in reply to yours of the 14th ultimo, to state that the Rappahannock River below Fredericksburg is situated in the customscollection-district of Tappahannock, Va.

2d. That during the fiscal year ending June 30, 1874, there was no revenue collected at the port of Tappahannock.

3d. There is no other port of entry on the Rappahannock below Fredericksburg. There is a port of delivery at Urbana, on said river.

4th. There is a very extensive freighting business carried on by means of the river on the following articles, viz: Grain, tobacco. cord-wood, ship-timber, railroad-ties, lumber, oysters, &c.

Very respectfully, your obedient servant,

JAMES J. McDONALD,
Special Deputy Collector.

Maj. WILLIAM P. CRAIGHILL,
Corps of Engineers.

U 14.

IMPROVEMENT OF AQUIA CREEK, VIRGINIA.

It having been found inexpedient to begin the improvement with the small appropriation of $1,500 of June 10, 1872, it was held in hand to await a further appropriation by Congress. The new appropriation of March 3, 1873, was $2,000. Proposals were received April 29, 1873, for excavating a channel from the draw in the railroad bridge toward the "Narrows" above, to be 20 feet wide at bottom and 4 feet deep at mean low-water, but they were too high, and their rejection was recommended, and that the work be again postponed. A special report was made May 21, 1874, as follows:

UNITED STATES ENGINEER OFFICE,
Baltimore, Md., May 21, 1874.

GENERAL: In reply to telegram of this date I have the honor to state, that I should be unwilling to promise any useful results at Aquia Creek for a sum less than the estimate submitted with my last annual report; and it is proper I should add that, on account of the unusual softness and fluidity of the material there, the channel excavated even with that sum would, in all probability, not be permanent, but would very soon require re-excavation.

Constant dredging will be needed to keep a channel open there, at a greater expense, it now seems to me, than the interests involved justify. This is my candid opinion. Still, if Congress should think fit to appropriate any sum in addition to funds now available, I should endeavor, if charged with its expenditure, to use it so as to produce some useful effect, however small and temporary that effect might be.

Very respectfully, your obedient servant,

W. P. CRAIGHILL,
Major of Engineers.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

Aquia is in the collection-district of Alexandria.

The total thus far appropriated for this work is $3,500. The estimate was $18,000. Hence it remains to appropriate $14,500 to fill it. The whole amount should be available at once, or the work not begun.

Observation of several years induces the opinion that it is doubtful whether the interests involved are of sufficient value to justify so large an expenditure at this locality, when the probabilities of a success in the permanence of the improvement are small.

Financial statement.

Balance in Treasury of the United States July 1, 1873	$2,900 00
Amount in hands of officer and subject to his check	466 45
Amount expended during the fiscal year ending June 30, 1874	137 39
Amount available July 1, 1874	3,229 05
Amount required for the fiscal year ending June 30, 1876	14,500 00

U 15.

IMPROVEMENT OF NOMINI CREEK, VIRGINIA.

On the 30th of June, 1873, Mr. G. H. Ferris was engaged in excavating a channel through the bar at the mouth of the creek. After completing two cuts, connecting deep water in Nomini Creek with that of the bay, operations were suspended September 17. The examination made immediately after the close of work showed a channel about 50 feet wide at bottom, with a ruling depth of 7 feet at mean low-water. A re-examination of the artificial channel made in June, 1874, disclosed the fact that the channel maintained quite well its former dimensions, although some filling has taken place.

Nomini Creek is in the collection-district of Alexandria, which is also the nearest port of entry.

No proposals were received during the year.

Cost of improving creek, as per original estimate, $20,000. Appropriated March 3, 1873, $10,000, and June 23, 1874, $6,000—total, $16,000. To complete the estimate rigorously $4,000 are needed; but this is a case where the whole appropriation should have been made at once.

Interruption of the work has caused it to be more expensive, hence $6,000 are asked for year ending June 30, 1876.

Financial statement.

Balance in Treasury of United States July 1, 1873	$7,500 00
Deduct amount expended in fiscal year 1872–'73	850 46
Amount appropriated by act approved June 23, 1874	6,000 00
Amount expended during the fiscal year ending June 30, 1874	5,619 94
Amount available July 1, 1874	7,029 60
Amount required for the fiscal year ending June 30, 1876	6,000 00

U 16.

IMPROVEMENT OF THE MES RIVER, VIRGINIA.

The operations of the year have been of the same character as of the previous year, and may be described in general by the language used in the last annual report, viz:

Removing rocks from the channel near the city of Richmond, especially at the Rockett's Reef, dredging on the bars, and depositing the material behind dikes constructed partly for that purpose and partly to rectify the banks and contract the waterway in some places where needed.

The work has been exceedingly unfortunate in losing, by death, Mr. W. G. Turpin, who was the assistant engineer on the part of the United States and the engineer for the city in the joint operations for the improvement of the river. He was prostrated by typhoid fever in October, 1873, and, after continuing in a feeble state of health, finally passed away quite suddenly in June, 1874. I have felt this stroke severely, as my relations with Mr. Turpin, both official and personal, were of the most agreeable character. He was an upright, zealous, and efficient officer. In addition to this loss, the work suffered another in the death of Mr. N. B. Randolph, clerk and general assistant, who died in February, 1874.

On the 30th of June a channel is found 125 feet wide, and with a depth of 15½ feet at high-water, through the Rocketts' Reef, which has been always the most serious and dreaded obstruction in reaching the

wharves of the city. Other dangerous masses of rock have also been taken out near that channel and in other parts of the river in the vicinity. The means used in this work are the diamond drill as the borer, nitro-glycerine as the explosive, a simple hoisting-apparatus for lifting the large masses, the assistance of divers being necessary. Much rock is so shattered by the explosions as to be reduced to a fit state for taking out by the buckets of the dredges. The following are reported as the quantities removed on the reef and near, viz:

Nine hundred and fifty-eight cubic yards of rock in masses, 1,631 yards in small pieces, lifted by the dredges, and 889 yards of sand and gravel. One pound of nitro-glycerine has been used to each 2½ cubic yards of rock. The nitro-glycerine is made and used by Mr. C. L. Kalmbach. Ninety-five holes have been drilled, in length aggregating 819 feet.

The sickness and death of Mr. Turpin and Mr. Randolph have left the statistics of the year in a somewhat unsatisfactory condition. From the 1st of October, 1873, to June 30, 1874, about 89,000 cubic yards of sand and river-sediment have been taken out from the bars near the city. The principal dike built has been near Richmond Bar, near the left bank of the river, of which 1,515 feet have been completed up to June 30, 1874. It was begun in February, 1874.* A portion of the dike on the right bank, which was built several years ago, by Captain Minor, for the city, nearly opposite this new dike, has been taken up, as it was improperly located and in a position to do injury to the river.

Some extracts of interest are appended below, taken from the last report made by Mr. Turpin in his capacity of engineer for the city. He explains the method of conducting the joint operations by the United States and the city of Richmond, and refers to other important matters connected with the improvement, in which he took such an intelligent and active part.

A careful resurvey of the river, extending from the ship-lock at the city to Trent's Reach, and including the Dutch Gap Cut-off, was commenced in November, 1873, and completed in March, 1874, by Mr. William Popp. Its object was to note the changes made by nature and art since the last maps and the partial examinations of 1870, and to give the basis for a careful revision of the estimate for the continued improvement of the river. This estimate is submitted below. Two estimates are given, one for a channel 180 feet wide and 15 feet deep at high-water, the other 180 feet wide and 18 feet deep at high-water. It is only necessary at present to consider the smaller depth. The greater depth can be given when the trade on the river requires, which is not the case at present. The operations of the year ending June 30, 1876, will have for their object the attainment of a depth of 15 feet at high-water, as high as Richmond, and of as great width as the funds will admit.

The appropriations by Congress have been $50,000 July 11, 1870; $50,000 March 3, 1871; $50,000 June 10, 1872; $75,000 March 3, 1873; $50,000 June 23, 1874; total, 275,000, of which there is now available, in money and property, $70,000.

The estimate of 1870 for dredging, diking, and rock-excavation, for a channel 180 by 15 at high-water, was $120,000. Up to that time no work had been done on the James River by the United States. The prices in that estimate were taken from information obtained in Richmond and supposed to be reliable. Actual experience shows them to have been too low. Besides the work done in dredging, diking, and rock-excava-

* Two thousand one hundred and fifty feet of diking at north end of Drewry's Island have also been built during the year.

tion, which were included in the estimate, $35,000 of the above sum were spent in removing wrecks which greatly obstructed the channel, and $5,000 in deepening a portion of Dutch Gap Cut-off to 18 feet, which was found necessary. In the report of 1870 it was stated that, in a freshet-river like this, $15,000 would be annually required to keep the channel open when made. This expense has fallen and will fall on the annual appropriations from 1870 to 1874 inclusive. It is now estimated, after the experience of these years, that the sum of $117,000 will be needed to open a channel 180 feet wide by 15 feet deep at high-water, to which add for annual repairs after freshets, to include June 30, 1876, $30,000, and deduct $60,000, the sum now available, and we have $87,000 as the sum asked for the year ending June 30, 1876.

A letter from the collector of customs at Richmond, Va., dated August 14, is appended hereto.

Financial statement.

Balance in Treasury of United States July 1, 1873	$115,000 00
Deduct amount expended in fiscal year 1872–'73	8,358 23
Amount appropriated by act approved June 23, 1874	50,000 00
Amount expended during the fiscal year ending June 30, 1874	93,596 46
Amount available July 1, 1874	63,045 31
Amount required for the fiscal year ending June 30, 1876	87,000 00

Estimate for James River improvement, 1874, the depths being taken at mean high-water.

Canal-locks to Rocketts':	
Channel 180 feet by 15 feet, 2,500 cubic yards, at $1	$2,500
Channel 180 feet by 18 feet, 300 yards rock, at $10	3,000
24,100 yards other material, at $1	24,100
Across Rocketts' Reef:	
Channel 180 feet by 15 feet, 1,000 cubic yards rock, at $10	10,000
Channel 180 feet by 18 feet, 3,000 cubic yards rock, at $10	30,000
Rocketts' to lower end of Drewry Island:	
Channel 180 feet by 15 feet, 54,000 cubic yards, at 60 cents	32,400
Channel 180 feet by 18 feet, 174,000 cubic yards, at 60 cents	104,400
Across Richmond Bar:	
Channel 180 feet by 15 feet, 600 cubic yards, at $10	6,000
78,000 cubic yards sand, at 45 cents	35,100
Channel 180 feet by 18 feet, 1,200 cubic yards rock, at $10	12,000
214,000 cubic yards sand, at 45 cents	96,300
Dikes, 3,000 cubic feet, at $3.50	10,500
Across Warwick Bar:	
Channel 180 feet by 15 feet. No excavation.	
Channel 180 feet by 18 feet, 40,000 cubic yards, at 45 cents	18,000
Dikes, 1,350 feet, at $3.50	4,725
Kingsland Reach:	
Channel 180 feet by 15 feet. No excavation.	
Channel 180 feet by 18 feet, 13,000 cubic yards, at 45 cents	5,850
Dikes, 2,200 feet, at $3.50	7,700
Dutch Gap Cut-off:	
Channel 100 feet by 15 feet. No excavation.	
Channel 120 feet by 18 feet, 23,700 cubic yards, at 60 cents	14,220
Channel 180 feet by 18 feet, 85,000 cubic yards, at 60 cents	51,000
At Aikens's, (old estimate as for quantities:)	
Channel 180 feet by 15 feet. No excavation.	
Channel 180 feet by 18 feet, 48,000 cubic yards, at 35 cents	16,800
Dikes, 1,200 feet, at $4	4,800
Harrison's Bar:	
Channel 180 feet by 15 feet. No excavation.	
Channel 180 feet by 18 feet, 1,500 cubic yards, at 50 cents	750

Total amount.

Channel 180 feet by 15 feet	$110,720
Add for contingencies	6,280
	117,000
Channel 180 feet by 13 feet	388,925
Add for contingencies	20,000
	408,925

Extracts from report of Mr. W. G. Turpin, while engineer for the city of Richmond.

RICHMOND, VA., *January* 19, 1874.

SIR: I submit the following report of the operations for the improvement of James River for the past year, giving the condition of the improvement-fund, the expenditures made during the year by order of the committee, in making such additions to the machinery and outfit owned by the city as was indispensable to an efficient conduct of the work, and in keeping such machinery in good working-order, and under their agreement with the United States engineer-officer in charge to supply such machinery and outfit as would be sufficient to meet the outlay they were prepared to make in the prosecution of the work.

In an elaborate report submitted to the council in May last, after the complete inauguration of the joint arrangement for the river improvement, and the satisfactory demonstration of the advantages resulting therefrom, and the certainty of executing a greater amount of work than under any other plan, and at less cost, the council was informed of the arrangement.

Briefly once more, that no one who will take the trouble to read this report may misunderstand the arrangement, I detail it: The joint committee agree to keep their machinery in good order, and from time to time make such additions as to keep the outfit up to the most efficient standard. The United States engineer-officer to have control of the machinery so far as operations on James River were concerned, he agreeing to pay all salaries and wages connected with the machines, and for the distribution of the materials when deposited behind the dikes; to furnish all the fuel and lubricators necessary to run the machines. Thus far, this arrangement went into effect January 1, 1873. On the 1st of March, all expenses attending the construction of dikes, office-rent, clerical salaries, and attendant expenses were assumed by the Government. The arrangement was terminable at the pleasure of either party; so the matter has always been under the control of the committee, if the interests of the city were and could be separate from those of the Government, in the improvement of James River. I was active in bringing this arrangement about, seeing very clearly that nothing I could do would tend so much to the successful progress of the work. I am glad to know that my expectations have been fully realized. In this connection it may be gratifying to the committee to know that their efforts in furtherance of all plans for a vigorous prosecution of the work have met the cordial indorsement of Colonel Craighill, United States Engineer Corps, controlling the improvement of rivers and harbors in Virginia.

* * * * * * *

The machinery of the city is now in first-rate order; $150,000 would not now supply as complete or more serviceable outfit than that owned by the city.

Without addition to the present outfit, and having no unforeseen accidents, I think that $1,000 per month, or, say, $12,000 for the year 1874, will be ample to conduct the work as now carried on in conjunction with the United States. As we are reaching work of easier execution, I am strongly in hopes that the expense of repairs will be less than I have estimated. One thing is certain: they will in the future, as in the past, be kept as low as possible. None that were not needed have been or will be made, but the committee are assured that the most expensive work done is that attempted in submarine operations with inefficient machines; hence, as is my custom, and it is true economy, our machines have been kept up to the highest standard of efficiency.

* * * * * * *

During the year 122,686 cubic yards have been dredged and placed behind the dikes and distributed; 2,540 linear feet of dikes have been completed; 738 cubic yards of rocks, broken by blasting at Rocketts' Reef, were raised by one of the dredges; 105 bowlders, requiring the aid of divers, have been removed from the channel between the brick-yard and the lower point of Drewry's Island, causing the loss of much time and damage to the machinery. These bowlders raised varied in size from one-half to six cubic yards, and hundreds of others were raised by the ordinary process of dredging.

Many of them had large masses of copper-sheathing ground into them, showing that they had been repeatedly struck hard by passing vessels.

The United States expenditure during the same period in conducting their part of the joint operations was $62,439.27, or $5,203.27 per month, making the cost per cubic yard, inclusive of the dikes, 50.9 cents per yard. The repairs, or portion borne by the city, was $18,151.95, or 14.7 cents per cubic yard. The total cost per yard being 65.6 cents. The dikes completed will contain many thousand cubic yards in addition to what has been deposited behind them. Before the joint arrangement for the conduct of the work could be entered into, advertisements were extensively published, asking proposals for the execution of this work by contract. The lowest bid received was $1.50 per cubic yerd, and only sand, gravel, and small bowlders were covered by the bid, and exclusive of dikes, that were to be furnished for the deposition of the material, either by the city or the Government. Under this law the bid could have been accepted, but was not, and under authority from the War Department, Colonel Craighill accepted my plan, now in successful operation. At $1.50 per yard the 122,686 cubic yards would have cost $184,029. and long before the end of the year all the funds of the Government would have been exhausted. At the beginning of the year 1873 the funds of the city were inadequate to have operated their machinery anything like to its capacity for the year. So that but for this joint operation work would now be suspended on James River. As it is, the Government fund will carry the work, on the present scale, to the first of August instant, even should no further appropriation be made by Congress, in addition to continuing the removal of Rocketts' Reef.

The operations at Rocketts' Reef are conducted by the Government wholly. Since the work was commenced, in June, 1872, 2,102 cubic yards of solid rock have been blasted from the bed of the river, and removed, and 4,307 cubic yards of the hard, disintegrating rock have been removed by dredging. During the next six months the danger and obstruction to navigation at this point will all be removed. We have now a channel of 70 feet in width, with full 15 feet at low-tide, which will give upwards of 18 feet at mean high-water.

The year was not a favorable one for submarine operations. During the year 55½ days were lost from ice, high-water, and currents so strong, consequent therefrom, that the machines could not hold their positions in the channel. In the five first months in the year the rain-fall in the city was 27 inches, and for the whole year was 53.32 inches. During the month of May, for seventeen consecutive days, every machine was idle, the river being from 2½ to 8 feet above ordinary high-water. I have, in a number of previous reports, endeavored to explain that the difficulties, and, for the distance, the greatest proportional cost attending the improvement of James River was from the outlet from the docks to the lower point of Drewry's Island. Numerous points of solid rock are found in the harbor; some of the most dangerous of these have been removed. Then, the Rocketts' Reef, 460 feet long, over which space a large mass of solid rock is encountered. Then, from the brewery to the brick-yard was the shoalest reach on James River, at ordinary high tides, affording not over from 10 to 10½ feet of water. The material excavated from this reach almost rivaled rock in toughness and difficulty of excavation. Several times I almost despaired of its excavation by dredging-machines; but perseverance at last enabled us to complete a channel through it about 100 feet wide, and with no less than 16 feet water at mean high-tides. Over most of the distance the standard depth of 18 feet was secured. Where we did not obtain 18 feet narrow ledges of solid rock were encountered, that will be removed by drilling and the use of nitro-glycerine. These points are not numerous or extensive, and such removals are made by the United States engineers exclusively, and on Government account. Had this work not been accomplished with dredging-machines, its cost from the use of explosives would have been very great, so great that I would hardly have deemed its undertaking at this time or within the past three years judicious, and it would have required years for its execution. From the brick-yard to the lower end of Drewry's Island there was a gradual improvement, the disintegrating rock gradually sinking and more sand and gravel being encountered, until, at the lower end of the island, from 19 to 20 feet of water at high-tides can be obtained without encountering it. The opening of this reach and removal of Rocketts' Reef was the key to reaching the harbor of Richmond. I did not deem it judicious to operate on the lower reaches that are easy of execution, until it was demonstrated that this work could be accomplished. In this view of the case I was fully sustained by Colonel Craighill and the committee, though the general plan on rivers is to begin on the lower reaches and work up-stream. All material dredged from the river is placed behind dikes constructed for that purpose, and a rectification of the width of the river. I am aiming on this reach to secure an average width of about 800 feet. These dikes also, while securing the material dredged from the channel, give a certainty of not again having to remove it from the channels. They also have the effect of making the currents uniform, and tend to prevent accretions on the reaches, where they can be constructed. I am gratified to know that these improvements are having this effect. They also have the effect, in connection with the removal of the bars, of increasing the tidal flow, and when completed, in accordance with the proposed plan for the river

improvements, will have a marked effect in increasing the duration of the flood-tide, and such increase will cause an increase in the height of the flow, the difference here between the duration of the ebb and flow tides being about one hour and thirty-five minutes. Whatever tends to their equalization is of great importance, especially as the larger class of vessels seeking our harbor must be governed by high-tides. During the past year the tidal-flow, owing to the general prevalence of east and northeasterly winds, was uncommonly good, for months averaging a mean rise of 4 feet, and on such tides 13 feet could be brought to the city with ease.

The necessity of going so fully into minute details connected with the operation of the Government operations, so that a correct understanding may be had of the general condition of the improvement, must be my apology for the length of this report.

At the expense of being tedious, I will submit a few observations, not for the benefit of the committee, but for those who have not the opportunity of familiarizing themselves with the improvement. I hear the remark frequently made that the money is being wasted; that no good was being done to the river; that there is no more water in the river than before the work began; that it was nonsense to attempt to improve James River. While the work, as far as it has progressed, has been costly and tedious of execution, I do not feel that the money spent in its execution has been wasted in any particular. Large expenditures had to be made in the purchase and construction of costly machinery and other appliances, without which nothing could be accomplished, and the work executed will compare most favorably proportionally to the difficulties attending its execution, with any similar work in the United States. I make this statement from an extended and careful comparison with prices paid at the numerous points throughout the country where rivers and harbors are improved by the United States. The city of Glasgow is always held up as a model for all others situated inland as an example of what can be accomplished by those determined to become commercial.

That city owns, and keeps constantly at work on the Clyde and in the harbor, six dredging-machines, either one of which has the capacity of doing more than double the work of the three machines owned by this city. The engineer of the Clyde Trust, reports, in 1872, the last that I have seen, a removal of 345,209 cubic yards of material, as deposited by the city sewers and from the higher reaches of the river, and this is a yearly tax. Their yearly expense is about $177,000. The value of their dredging-plant is about $700,000. During the twenty-six years ending with 1871, the expenditure was $25,000,000, and 13,617,000 cubic yards were removed. In addition to the large harbor facilities for shipping, a new dock is now under construction, estimated to cost $7,500,000. In fact, from a stream fordable at many points below Glasgow, and at high-tide with not over 3½ feet water at the city, a magnificent ship-canal, about 400 feet wide and eighteen and a half miles long, has been constructed, affording, at high tide, 25 feet water, and with a low-water depth of 15 feet, the tidal flow being 10 feet. Less than one-eighth of the number of cubic yards excavated on the Clyde will give 15 feet water at mean low-tides from Richmond to Hampton Roads, a distance of one hundred and four miles. For many of the facts connected with the Clyde I am indebted to the managing director of the improvement, who kindly answered numerous inquiries propounded to him by me, and to Stevenson's work on Canal and River Engineering, edition of 1872. A comparison of the prices of similar work on the Clyde, where labor is much cheaper than here, is not at all unfavorable to those on James River. By the termination of the present fiscal year, 30th of June, (instant,) the city of Baltimore, in addition to the large amount annually expended in clearing their basin and immediate harbor, (exceeding the average yearly expenditure on the part of this city in improving the river,) will have spent in two years $400,000 in widening and deepening the two channels leading from the bay into the Patapsco River, and in giving them 24 feet water at mean low-water; the Government spending on the same channels, in the same time, $350,000. So it will be seen that those who help themselves are those the most liberally aided. Those who will think that the opening of the shoalest reach on the river, over one mile long, and of material of the hardest kind ever attempted by dredging-machinery, is a waste, or that the removal of a long and dangerous reef of rocks just at the entrance to the harbor, the removal of dangerous ledges in the immediate harbor, the removal of hundreds of bowlders and detached masses of granite from the channel, large numbers of them requiring the aid of divers and the powerful machinery of the United States to raise them from their beds, is a waste, must feel but little interest in the commerce of the city.

The practicability as well as the feasibility of the improvement of James River has repeatedly been decided by the highest professional authority. If the improvement of rivers and harbors was an untried theory, there might be some hesitancy in making the experiment with James River. But with a mean rise and fall of the tides of nearly 4 feet, and the immense natural discharge of the river, there is water enough for an improvement, the cost of which will be small in comparison with the great interests served and to be served. No one proposes to create more water, but the intention and plans proposed are simply to conserve the ample supply in existence, and make it serve the purposes of navigation. This is accomplished by removing the bars, contraction of

water-way at points that are judicious, rectifying the direction of the channel at some points, and by these means reducing the slope of the bed of the river for a few miles; hence the velocity of the water is diminished, and the result of an improved navigation is secured. Pass to Drewry's Bluff, when the velocity is but slight at slack water, and there is water enough for any improvement that the most sanguine may have dreamed of, and between Richmond and City Point the addition to the natural discharge of the river is one not appreciable. This increase in depth is due to the low velocity, and this water daily passes by our city. We have, for a few miles only, to produce the same condition, or an approximation, and the benefit is at our wharves. The United States engineers have in the most emphatic manner, after careful study, indorsed the practicability of the improvement, and each year recommend the appropriation for carrying it out, and as the improvement has progressed have increased their yearly estimates. But no surer means of discontinuing these recommendations, and consequently the appropriations, can be fallen upon than for them to be satisfied that, in the sense of the community which the object is to benefit, it is believed that the money is thrown away, and that no good has been or is to result from the expenditures.

I could adduce innumerable instances of the successful improvement of rivers and harbors in our own country and Europe. In the latter country numerous streams, that do not compare in natural flow of water with many of our creeks, are at great cost improved, and the result is large inland commercial cities; but the details would make this report, already long, an unreasonable length.

In a previous report I called the attention of the committee to the great improvement in the river that I considered practicable, at a moderate outlay, from the restoration and repair of the dikes between this city and City Point. Thousands of acres are now daily submerged, and could these dikes be restored, and this immense waste of water be prevented, a marked improvement in the strength and duration of the flood-tides would be the result. This waste of water, could it be confined to the river, would make a depth of thirteen inches from this city to City Point.

* * * * * * *

This report would have been submitted at the close of the year, but a protracted illness and tedious convalescence must be my apology for the delay. Thanking yourself and committee for the encouraging and hearty support of all my plans and suggestions for the successful conduct of the work, and the uniform personal consideration received at their hands,

I am, very respectfully, your obedient servant,

WALTER G. TURPIN,
Engineer on part of the City.

Col. ALBERT ORDWAY,
Chairman Joint Committee Improvement James River.

Commercial statistics.

CUSTOM-HOUSE, RICHMOND, VA.,
Collector's Office, August 14, 1874.

SIR: Your letter to me, dated 14th ultimo, would have been answered before this, but I desired to procure information not then in my possession, and which I hoped might add weight to the rather slender data furnished by the records of this office.

In reply to your first inquiry—what amount of customs-revenue was collected at this port during fiscal year ending June 30, 1874—I refer you to the following figures, viz 1871–'72, $104,645.83; 1872–'73, $72,750.62; 1873–'74, $34,135.29; which show rather discouragingly, even when it is borne in mind that the duty on salt was reduced in 1872 from 24 cents per 100 pounds to 12 cents per 100 pounds, and that the importation of iron from foreign countries to Richmond was first curtailed by the great advance caused by strikes in England, and next, and as at present, kept down by the effects of the panic of 1873. The amount of merchant tonnage, on the contrary, shows an increasing tendency. During 1873, the foreign commerce (tonnage) noted on records of this office stood:

	No.	Tons.	Total.
Foreign vessels entered	21	5,927	
American vessels entered	14	2,283	
			8,210
Foreign vessels cleared	31	11,530	
American vessels cleared	29	9,773	
			21,303
During first seven months, 1874:			
Foreign vessels entered	12	4,243	4,243
American vessels entered	None.		
Foreign vessels cleared	25	8,066	
American vessels cleared	12	3,807	
			11 873

As by far our heaviest business is during the last four months of the year, it is already certain that the tonnage engaged in foreign trade with Richmond during 1874 will much exceed that of previous years.

Extension of railroad connection with the West has brought to our flouring-mills an increased supply of wheat, and the Chesapeake and Ohio Railroad, developing an entirely new traffic, has delivered at its wharves on James River, for water-transportation, some 36,000 tons of produce of various kinds during the six months ending June 30, 1874.

The deepening of the channel of James River, though satisfactory as far as carried, has been only partial; and while obstructions which formerly existed in certain localities have been removed so as to give sufficient depth of water to allow safe passage of vessels trading with this port, yet in other places obstructions still exist which render the improvement incomplete; hence, that full advantage may be realized from what has been done, it is imperatively necessary that a corresponding depth should be given at those points, thus rendering necessary a further improvement of the channel, so as to furnish a continuous depth of water from the wharves at Richmond to City Point.

Vessels now arriving in the James River from foreign ports bound for Richmond are compelled to discharge cargo at City Point until their draught of water is reduced to 11½ to 12 feet before they can ascend the river to Richmond. This entails heavy expense, and causes delay and embarrassment to both captain and consignee. Vessels, on the other hand, loading for foreign ports, can only ship a portion of cargo at Richmond, and must (if over 200 tons) drop down to City Point to complete lading. This is expensive to shippers, and takes the loading of their property away from that personal supervision which is so desirable on the part of the shippers.

The exports contributing much more to the real wealth of the country, and therefore of much greater importance, are still more seriously affected by the present obstructions to free and safe navigation of the James River, and the general commerce of the country is thereby embarrassed. A comparatively limited section feels the effect of the imperfect navigation of the river upon imports destined for this port, which might, without great inconvenience, be received through other ports. But such is not the case with regard to articles of peculiar product or manufacture for which Richmond is and must be a special and almost exclusive market and direct outlet, as flour for the Brazilian market and tobacco for the European markets.

The injury to commerce by existing obstructions to free navigation of the James River is not, however, confined to Richmond, or even the State of Virginia, but affects the commerce of the entire country. The extent to which the injury reaches it is impossible to state; but it is well known that every impediment to cheap and rapid transportation tends to diminish the products of a country; as they are increased always by increased facilities of moving them to points where they are needed for consumption.

The area of country at this time tributary to the commerce of Richmond has been greatly enlarged by the extension of inland communication with the West and Southwest, and is likely to be extended on a vast scale when the western connections, now in progress, shall have been completed.

In considering, therefore, the benefit likely to accrue to the commerce of the country from prosecuting the improvement of James River, it is proper to take a much wider and more national view than is presented by the present limited commerce of Richmond, and to look to those more remote sections which are now seeking an avenue to the markets of the world by the most direct route to the seaboard.

The fostering care of the General Government is now directed to the subject, (especially with reference to the completion of the James River and Kanawha Canal,) and the statesmen of the country are with anxious solicitude turning their attention to the pressing demands of our immense and rapidly-increasing inland population, whose labor is now unproductive to themselves and valueless to the world in consequence of their inability to have their products transported to the seaboard where markets await them.

The successful improvement of James River will at least furnish an additional outlet for this vast commerce, and induce it, or a portion of it, to seek it as the readiest avenue to the seaboard, and thence to markets at home or abroad.

In a national point of view, I therefore consider it very important that the improvement of James River should be prosecuted to a successful termination, in order to render practically available what has already been done, by furnishing a continuous depth of water for vessels drawing 13 to 14 feet.

I am, sir, very respectfully, yours,

CHARLES S. MILLS,
Collector.

Maj. W. P. CRAIGHILL, *U. S. Engrs.*

U 17.

IMPROVEMENT OF THE APPOMATTOX RIVER, VIRGINIA.

The operations of the year have been dredging in the Puddledock Cut, and above it toward the city of Petersburg, and the completion in July, 1873, of the deflector at the upper end of Puddledock Cut to a length of 250 feet. The new cut is now used altogether, but the width of 60 feet is too little.

The object of the dredging has been to give an available channel at mean low-water for vessels drawing 8½ or 9 feet. Such a channel was carried to within 3,500 yards of the city line by the 16th of May, 1874, when operations were suspended for want of funds. The new appropriation of $30,000 of June 23, 1874, will enable the work to be resumed at an early day, and the minimum channel brought to the city line.

A survey of the river was made in the winter of 1873–'74; but other more pressing duties have prevented the completion of the map as yet. The use of the old intricate channel is nearly given up, the old one being preferred by navigators, but, as before remarked, its width is insufficient.

A Board of Engineers in 1870 presented a project for the improvement of the river, to give a channel 60 feet wide with a depth of 12 feet at high-water, to cost $343,000, and for permanence of banks an additional sum of $125,000. This project was not carried out, as the city of Petersburg had spent a large sum of money on the improvement by a plan submitted by Mr. H. D. Bird. It was determined to make use of the city work as far as possible, as it had been carried so far.

In this connection reference is requested to my report published in the Annual Report of the Chief of Engineers of 1871, pages 606 and following. The Report of the Board of Engineers of September, 1870, having been omitted from the Annual Report of 1871, and being valuable in connection with the history of the improvement, is appended below.

The appropriations by Congress have been—

March 3, 1871, $50,000; June 10, 1872, $40,000; March 3, 1873, $30,000; June 24, 1874, $30,000. Total, $150,000.

The work has dragged through several years with these small appropriations; but important results have been gained, though the cost has been greater than it would have been if the operations could have been active and continuous with ample funds. It is now estimated that to gave a channel of 80 feet width and 10 feet depth at low-water will require the sum of $153,000, and an annual sum of $20,000 for repairs after completion. In every stream subject to copious sediment-bearing freshets such repairs will be always necessary. Required, therefore, to fill the estimate, $123,000, which is equal to the difference between $153,000 and $30,000, the last sum being the amount of the last appropriation and now available.

ESTIMATED COST.

To complete channel in Appomattox River 80 feet, by 10 feet at mean low-water, from Point of Rocks to city limits at Petersburg:

Earth and mud excavation:

South Channel, 70,000 yards, at 30 cents	$21,000 00
Puddledock Channel, 120,000 yards, at 30 cents	36,000 00
Petersburg Channel, 80,000 yards, at 30 cents	24,000 00
Stein's Upper Cut, 60,000 yards, at 30 cents	18,000 00

Rock-excavation:	
Stein's Upper Cut, 1,200 yards, at $10	$12,000 00
Piling:	
To close (to mid-tide level) old channel, upper end Puddledock, 640 feet, at $3.50	2,240 00
To close guts leading to old channel, 6,500 feet, at $3.50	22,750 00
Riprapping in place through Puddledock Cut, 7,500 yards, at $3.50	24,500 00
To divert mouth of Lt. Run:	
6,000 yards excavation, (earth, &c.,) at 30 cents	1,080 00
500 feet double piling and flooring, at $7	3,500 00

SUMMARY.

Earth and mud excavation, 336,000 yards, at 30 cents	$100,800
Rock-excavation, 1,200 yards, at $10	1,200
Rock riprap, 7,500 yards, at $3.50	26,250
Piling, 7,140 feet, at $3.50	24,990
Total	153,240

ANNUAL REPAIRS.

Dredging	$14,000 00
Repairs to banks and piling	6,000 00
Total	20,000 00

Financial statement.

Balance in Treasury of United States July 1, 1873	30,000 00
Amount in hands of officer and subject to his check, (including $286.44 percentage due on contracts not yet completed)	8,993 33
Amount appropriated by act approved June 23, 1874	30,000 00
Amount expended during the fiscal year ending June 30, 1874	38,347 12
Amount available July 1, 1874	30,646 21
Amount required for the fiscal year ending June 30, 1876	123,000 00

Bids opened at 12.5 *o'clock p. m., July* 25, 1873.

No.	Name.	Address.	Kind and number of machines.	Time.		Price per cubic yard.
				Begin.	Complete.	
1	F. P. Leavenworth	Petersburgb, Va ..	2 dipper-dredges now owned by city.	Sept. 1, 1873	May 1, 1874	$0 33
2	G. H. Ferris.....	Brooklyn	Osgood	Nov. 1, 1873	July 1, 1874	24¼

Contract awarded to G. H. Ferris, at 24¼ cents per cubic yard.

Report of H. D. Bird, Assistant Engineer.

PETERSBURG, *July* 2, 1874.

SIR: I have the honor to report to you the amount of work done on this improvement for the twelve months ending June 30, 1874.

Contractor Burch completed his contract for dredging out the middle of Puddledock Cut on the 28th of February last, and removed between July 1, 1873, and that date 32,181 cubic yards of material, including several large bowlders.

Contractor Ferris commenced work on the 9th of December, 1873, at the point where Burch's contract was to terminate, and dredged up the Petersburg Channel until the 16th of May last, when the work was suspended for want of funds. During the period he was at work, he dredged out a length of 6,600 feet of channel, 80 feet wide at bottom, the two middle cuts (40 feet) 10 feet deep below low-water, and each outside cut

(20 feet) 7½ feet deep; and removed 90,914 cubic yards. This, added to the work done by Burch, makes the whole amount of material taken out during the twelve months 123,095 cubic yards. Nearly all this was carried off in scows and deposited in the deep water below the Point of Rocks.

We also completed in July last, with hired labor, 250 feet of a deflector at a point 2 miles below Petersburg, and built at the same place an abutment to protect the old piling.

The dredging has now reached a point 3,500 feet below the city line. All the work stands well so far, and vessels have used the new channel for the last twelve months.

Respectfully submitted.

H. D. BIRD,
Assistant Engineer.

Col. W. P. CRAIGHILL,
Corps of Engineers, U. S. A.

COMMERCIAL STATISTICS.

PETERSBURG, VA., *July* 20, 1874.

COLONEL: According to your instructions, I have obtained and beg leave to submit the following information in regard to the business, &c., of this city for the twelve months ending June 30, 1874.

Respectfully, your obedient servant,

H. D. BIRD,
Assistant Engineer.

Col. W. P. CRAIGHILL,
Corps of Engineers, U. S. A.

Petersburg is the collection-district in which the Appomattox River is situated.

Population.

By last census	18,834

Duties, &c.

Custom-house	$32,673
Internal-revenue	1,703,800
Post-office	17,316
	1,753,789

Value of property.

Real estate	$5,612,580
Personal	3,824,015
Total	9,436,595

Taxes paid.

State	$61,405
Municipal	170,306
Water	13,295
Gas	44,000
Total	289,006

City property.

Expended on river improvement	402,900
Water-works	125,000
Land and buildings	111,000
Public-school houses	57,000
Wharves	16,540
Steam fire-engines	6,300
Railroad stocks	300,000
Bonds receivable	249,982
Total	1,268,722

Tonnage of river.

	Tons.
25 steamers and 156 schooners	16,400

Tonnage of railroads.

Petersburg and Weldon	57,238
Petersburg and Richmond	91,[illegible]
Petersburg and Lynchburg	235,787
Petersburg and Norfolk	176,030
Total	560,943

Agricultural products sold in city.

41,504 bales cotton	$2,863,776
15,330 hogsheads tobacco	1,533,000
550,000 bushels wheat	1,100,000
600,000 bushels corn	540,000
25,000 bushels pea-nuts	60,000
1,700,000 pounds sumac	25,500
Oats, hay, &c	60,000
Total	6,182,276

Merchandise sold.

Groceries	$4,000,000
Dry-goods	1,350,000
Clothing, hats, caps, boots, and shoes	1,050,000
Hardware, stoves, and tin	275,000
Drugs, medicines, and paints	150,000
Crockery and stone ware	60,000
Iron and steel	50,000
Hides and leather	80,000
Books, stationery, &c	40,000
Fertilizers	250,000
Lumber	300,000
Coal and fire-wood	300,000
Miscellaneous	100,000
Total	8,005,000

Manufactures.

7 cotton-manufactories, value of products	$1,009,850
16 tobacco	3,325,132
4 flour-mills	850,000
5 cane-mills	270,000
2 iron-works	190,000
4 printing-offices	65,000
1 paper-mill, 1 brewery, 1 distillery, 4 planing-mills; wagon, carriage, and other shops	200,000
Total	5,909,982

Moneyed institutions.

Citizens' Bank	$325,000
Commercial Bank	120,000
Planters and Mechanics' Bank	250,000
Petersburg Bank	66,000
Petersburg Savings and Insurance Company	350,000
Farmers and Merchants' Insurance Company	100,000
Virginia Life-Insurance Company	360,500
People's Savings-Bank	20,000
Deposits	1,200,000
Total	2,791,500

Recapitulation.

Value of real and personal property	$9,436,595
Value of city property	1,268,722

Value of banks and moneyed institutions	$2,791,500
Value of agricultural products sold	6,182,276
Value of merchandise sold	8,005,000
Value of manufactures sold	5,908,992
Total	33,593,075

Taxes paid.

General Government	$1,753,789
State and city	289,006
Total	2,032,795

Reports of Board of Engineers of 1870.

UNITED STATES ENGINEER OFFICE,
Baltimore, Md., September 30, 1870.

GENERAL: The Board of Engineers convened by Special Orders No. 87, dated Headquarters Corps of Engineers, August 29, 1870, have the honor to submit the following preliminary report as to the improvement of the Appomattox River from Petersburg to its mouth.

A map accompanies this report, showing so much of the river as seems to require improvement at this time. Upon the map is exhibited the plan of improvement of the commission of 1852, as described in their report dated November 26, 1852, which is printed in Senate Doc. No. 1, Thirty-third Congress, first session, 1853, Part II, commencing at page 394.

Upon the same map is exhibited the plan of Mr. H. D. Bird, bounded by yellow lines. A copy of his report, dated August 20, 1869, is transmitted herewith.

The board, after inspecting the Appomattox, find a large amount of work already done according to Mr. Bird's plan, the adoption of much of which it is deemed expedient now to recommend.

Without at present discussing the details of the plans referred to, the board will state the reasons upon which are founded their objections to some features of both.

No place is found along the river from Petersburg to the Point of Rocks, where the use of jetties perpendicular to the banks seems the best expedient. Where a river like the Appomattox, whose tidal reservoir is very limited, is divided into two or more channels, that direction should be followed which will give a channel consisting of a succession of moderate curves, to the exclusion, on the one hand, if practicable, of long, straight reaches, and on the other hand, of abrupt bends. Abrupt bends, even if permanent, are objectionable by causing a great loss of momentum of the water, and are difficult of navigation from their shape. There is generally a liability to change of form, from the abrading influence of the water in its sudden and great variations of direction and velocity, and to the consequent formation of bars. These changes in the curves of the bends lead to variations in the position and condition of the channel which cannot be foreseen, and make the navigation intricate and uncertain.

In straight reaches, unless the cross-section is of the exact dimensions suited to the accommodation of a constant quantity of water flowing through it, (conditions which, in a river subject to the action of tides and freshets, can rarely, if ever, be fulfilled,) the channel will be found

shifting from place to place in the varying stages of the river, having its depth likewise variable.

In the curves of moderate curvature the channel will be found near the concave bank, and the depth of water, though somewhat diminished in passing from one concave to another, will not be strikingly variable.

In a river like the Appomattox, whose banks are of a character easily abraded by running water, especially when its velocity is greatly increased in time of freshets, the concave banks require revetments of some kind. No continuous revetment of the convex banks needs now to be prescribed. On the contrary, it is seldom prudent to confine a river between two fixed artificial banks, as the longitudinal distance between them can be suited to but one stage of water, and must be either too great or too small at all other stages.

Bearing these ideas in mind, which are thought to be correct, and believing further that the fundamental principle in all works of river improvement is to regulate the operations of nature after carefully watching them, but not to use undue restraints or to give too free scope for excesses on her part, and wishing to use as much of the work already done, according to Mr. Bird's plan, as would be likely to give good results in the desired direction, viz., the improvement of the river, the board made the following recommendations:

1st. That Stein's upper cut be not now opened. The channel now used in that portion of the river will have a good direction, if provided with a concave dike, on the broken black line, *a*, *b*, *c*. The plan proposed will prove less expensive, it is believed, than the reopening of Stein's cut, which would require the removal of a large quantity of rock. Mr Bird expects to give a channel in the rock but 60 feet in width by 12 feet in depth at high-water. A narrow channel in rock which is wholly unseen is always objected to by navigators, and undoubtedly with good reason.

In reopening Stein's upper cut the project of Mr. Bird is in direct opposition to that of the commission of 1852, which was approved by the Executive Department, to whose charge the work was assigned by Congress. It is a matter for consideration whether work thus done by the General Government in one of the navigable rivers of the country can with propriety be undone without the consent or sanction of the same authority.

But, on the other hand, should the increased trade of the city ever make necessary the additional wharf-room indicated on Mr. Bird's plan for the improvement of this part of the river, his arrangements for that purpose are good, and would require the reopening of Stein's upper cut, which the board would then approve, though now deeming unnecessary.

These basins in that part of the river, besides their use for the accommodation of shipping, would be at any time desirable as tidal reservoirs.

2d. From the lower end of Stein's upper cut C, to follow the channel marked out by the commission of 1852, to A, its intersection with the northern boundary of Mr. Bird's line, thence to *e*, to adopt his line, thus making use of the pile-work already executed by him from *d* to *e*, avoiding the long, straight reaches from *d* to *f*, and from *g* to *h* (Hare's Bar) in the line of the commission of 1852. The dredging from *d* to *e* to be confined to a space shown on the map by broken black lines, 60 feet in width on the bottom.

3d. A cut to be made from *e* to *h* by the dredges, 60 feet in width, and supported on the concave side by a dike.

4th. From *h* to *o* to follow the channel of the commission of 1852, putting in the curved dikes *k l* and *m n*, and trimming off the opposite points, and probably putting in another concave dike between the limits N and O.

5th. From O to follow the present main channel to the Point of Rocks.

The object of the board in making these recommendations for work to be done as soon as means are provided, is to give as soon as practicable, chiefly by dredging, a channel 60 feet wide and 12 feet deep at ordinary high-water; avoiding, as much as possible, abrupt bends or long straight reaches, or regulating them where they cannot be avoided entirely. The actually navigable channel of the river should not be abandoned without very strong reasons.

The board believe that Mr. Bird's expectation of the opening of his channel by the action of the water itself will not be realized. The case is very different from Mr. Stein's cuts, which were narrow and short.

At a point about midway between *f* and *g*, the river has but one channel of about the same width as in Mr. Bird's project. It is far from evident that the river would be able to maintain a channel of the same width in the position he has selected, and of a depth greater than in the present channel.

The feature of a near approximation to perfect straightness is considered a defect in the present case, and for that reason the channel of the commission of 1852, the channel now used, is preferred, except in the portion where the adoption of Mr. Bird's is recommended.

It is recommended that dredging, where necessary, be commenced at the lower ends of the cuts, and that a channel be first excavated, 60 feet wide at bottom and 9 feet deep at high-water, the depth of the cut to be next increased to 12 feet at high-water. When that much is successfully accomplished—and the board believe it may be—it will be time to think of getting a channel with great width and depth.

Any scheme of improvement of a river subject, like the Appomattox, to considerable freshets, must contemplate the occasional, perhaps the constant, use of dredges to keep open the artificial channel.

The board do not wish to be understood as saying that the line of which the improvement is recommended in this report would be regarded as the best, if a large sum of money would be available, as required in the progress of the work, and if nothing had been already done in carrying out particular plans.

The object has been to lay down a plan as good as existing circumstances permit, and such as, with the means likely to be furnished by the General Government and by the city of Petersburg, will result in a decided improvement of the river. As the work progresses the advantage or the necessity of adding to or modifying what has been recommended above may become apparent. Any well-devised scheme of river improvement should be progressive and elastic; and too great haste in executing may result in injuries which more deliberation, joined to careful watching of effects, would have avoided.

The citizens of Petersburg have certainly exhibited a most commendable willingness to help themselves. They have already taxed themselves heavily to provide money for the improvement of the river. In so doing they are at the same time contributing to the general good, and it is hoped they may be encouraged by receiving at the next session of Congress a liberal appropriation of money from the general Treasury.

It is proper to state that the city of Petersburg is now the owner of two good dredges of the Osgood pattern, and expects soon to procure a

third dredge and a tug-boat. There is on hand, also, a large quantity of material for piles and sheet-piling.

Drawings and estimates will be forwarded as soon as practicable, with such explanations as may seem necessary.

Respectfully submitted.

J. H. SIMPSON,
Colonel of Engineers, Bvt. Brig. Gen. U. S. A.
JOHN NEWTON,
Lieut. Colonel of Engineers, Bvt. Maj. Gen.
WM. P. CRAIGHILL,
Major of Engineers, Bvt. Lieut. Col.

Bvt. Maj. Gen. A. A. HUMPHREYS,
Commanding Corps of Engineers.

UNITED STATES ENGINEER OFFICE,
Baltimore, Md., November 19, 1870.

GENERAL: Referring to their report of September 30, 1870, the Board of Engineers convened by Special Orders No. 87, dated Headquarters Corps of Engineers, August 29, 1870, have the honor now to report further concerning the Appomattox River.

A copy of a communication from Mr. H. D. Bird, dated September 21, received in Baltimore October 8, is inclosed herewith, accompanied by a general plan of his line of improvement, and sketches illustrative of some of its details.

This plan differs favorably from that first proposed by him, and has been made less objectionable by his abandoning the idea of straight cuts, and giving to it more of the features of the line recommended by this board, viz, such easy curves as will as much as possible direct the current to the concave banks of the river; but his modifications do not by any means come up to the requirements deemed essential by the board. The curves of Mr. Bird's plan are not sufficiently defined to produce the desired result. There are also included in his communication an estimate and a summary statement of expenditures up to the date of his report.

It is believed that it would be found impossible by Mr. Bird to make a channel 12 feet in depth and of an average width of 350 feet within the limits of his estimate, or for twice its amount. It is to be observed, however, that a large part of the work of excavation is expected by him to be done by the river itself. It is far from certain that his expectations will be realized. It is considered, also, that his timber revetments are not sufficiently strong, and that they will need an additional expenditure of $2 per running foot in that portion adopted by the board.

In the report of September 30, a line was laid down by the board. A drawing is herewith, indicating the manner of construction designed for the dikes proposed as a part of that plan. The material dredged from the channel is intended to be used in forming the mass of the dikes. The timber facing will stand a number of years, a portion of it where most exposed being itself protected by riprapping. It will finally decay down to low-water mark. In the mean time the bank will be consolidating and preparing for its ultimate covering of stone.

A channel 60 feet wide at bottom, 12 feet deep at high-water, according to the plan recommended by the board, will cost, in round numbers,

$250,000. At the expiration of, say, ten years, an additional expenditure of $125,000 will be necessary to make the banks permanent. An annual expenditure of $10,000 will be required to keep the channel and banks in good condition.

ESTIMATE.

12,600 linear feet of dike, as per sketch, at $5 per foot	$63,000
3,050 linear feet Mr. Bird's dike strengthened, at $2 per foot	6,100
11,000 yards riprapping, at $3.50 per yard	38,500
450,000 yards material removed from channel and deposited in dike, at 30 cents per yard	135,000
	242,600
For permanent completion of work	125,000
Sum required annually for channel and banks	10,000

Respectfully submitted.

J. H. SIMPSON,
Colonel of Engineers, Bvt. Brig. Genl.
JOHN NEWTON,
Lieut. Colonel of Engineers, Bvt. Maj. Gen.
W. P. CRAIGHILL,
Major of Engineers, Bvt. Lieut. Col.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

Letter of Chief Engineer Lower Appomattox Company.

OFFICE LOWER APPOMATTOX COMPANY,
Petersburg, Va., September 21, 1870.

COLONEL: I take pleasure in complying with your request, to communicate to you what I have done and am still doing toward the improvement of the Appomattox River, as the engineer in charge of the works.

Before entering into the subject, it is proper to make a brief statement in regard to the river, and the efforts heretofore made to improve it, as a necessary preliminary to a right understanding of the case.

The Appomattox River rises in Appomattox County, over one hundred miles west of Petersburg, and empties into James River at City Point, eleven and three-eighths miles east of it. The tide flows up to the city, and vessels drawing seven and a half feet of water can come up to the wharves. The accompanying map will give you a more accurate idea of this part of the river, seven and three-quarter miles of which, from Petersburg to Point of Rocks, is the portion we have to improve. For the rest of the way down the channel is bold and deep enough to float any vessel that can reach City Point.

The city of Petersburg has long been the seat of a considerable commerce, and as early as 1824 the citizens turned their attention to the improvement of the river. A joint-stock company was incorporated, but with such a small capital that it was exhausted before the work was completed; but sufficient was done to effect a decided and permanent improvement in the navigation of the river.

The attention of the people soon afterward was entirely diverted from the river to the construction of railroads, which were then coming into vogue. Among the roads embarked in by our citizens was one to City Point, which was built, and it was thought that it would render unnecessary the further improvement of the river. From that time until 1854, the minds and means of our people were so absorbed in making railroads that the river seemed entirely forgotten. But as those roads, particularly the one through Lynchburg to the West, approached completion, and were beginning to bring to Petersburg a large amount of freight for shipment, the importance of making it the shipping-place instead of City Point became so manifest that the attention of our citizens was again turned to the improvement of the river. As the railroads to the West ran through many States, this improvement had become a work of national as

well as local interest, and our citizens very naturally applied to Congress for aid to make it. A small appropriation was made, and a commission of Government engineers was sent to survey the river and lay down a plan for the improvement. The work was commenced, but unfortunately the aid of the Government was not continued, the engineers were withdrawn, and the burden of continuing the work fell upon the city. The councils made liberal appropriations for the work, and it was prosecuted with considerable vigor up to the breaking out of the war. That of course suspended the operations, and soon after the river was dammed up as a military necessity. But the navigation had been so far improved that vessels drawing 9 feet water could reach the wharves, and the increase in the commerce of the city was beginning to show the value of the improvement to it and the country.

As soon after the war as the city council could command any means, an appropriation was made to remove the dam and to purchase a dredge, and work was again resumed. But it was found that the effect of the dam had been most disastrous to the navigation, for so many bars had formed during the four years of stoppage, that vessels drawing only 7 feet could not get to the wharves except on high-tides. From that time until last year the work was carried on, but owing to the poverty of our people the appropriations were so limited that there was but little improvement made in the navigation.

In July, 1869, the business prospects of the city had increased so much that the council determined to push the improvement on a large scale. A liberal appropriation was voted, a new committee was appointed, and a survey was ordered to be made to see if any improvement could be effected in the old plan of carrying on the works, and what it would cost. I was selected to make the survey, and upon my report the council called a vote of the people on the subject of raising the money for the work. The citizens responded in the same liberal spirit, and authorized an issue of city bonds for $200,000 for the purpose.

The bonds could not be negotiated until March of this year. The delay, however, was valuable to me, as it gave me time to make a more careful examination and study of the river, and to perfect the plan of improvement I had projected. This plan was indicated as much by the results plainly visible on the river of the former efforts made to improve it, as by those of my survey.

Between them both I believe I have elaborated a plan that will give us all that can be reasonably desired in the improvement. In a word, I feel confident that if the works are carried out on this plan we shall be able in time to bring to Petersburg any vessel that can reach City Point, an object which I conceive should always be kept in view in any scheme to improve the river, for anything short of it will not satisfy the future wants of the commerce of the city.

The first plan of improvement started on the river was to straighten it as much as possible, and to narrow the channel where it was too wide by jetties, so as to give the current such a direction and increased force as would enable the freshets and the tidal flow to scour the river deeper and keep it so. No dredging or excavation was resorted to on this plan, except in making two new cuts to straighten the channel. One of them was rock, which was blasted out to the required depth. The other was through an island, where a straight cut was made with shovels, ten feet wide at the water-line, four feet deep, and about three-quarters of a mile long. After this was done the channel on each side of the island was dammed up, and the cut was left to the action of the river. I was informed that this cut was scoured out to a navigable depth in about thirty days, and you will see in the map of the Coast Survey, made in 1853, twenty-nine years after the cut was made, that it averaged 200 feet in width, and was the deepest part of the improved portion of the river.

You observed, when you examined the river, that the water had broken through the sides of this cut in several places, into the old channel, which, of course, must have impaired its scouring power. But notwithstanding this, and the necessarily imperfect manner in which the works were constructed for the want of adequate means, it is recorded in the report of a committee of the city council made in 1849 that the navigation was then double what it was before the works were commenced, and that one bar, the worst in the river, had been entirely obliterated.

The plan adopted by the Government engineers was to dredge out a channel 60 feet wide at bottom and 12 feet deep, and erect such jetties as would be needed to give the current a proper direction and at the same time close up all branches and low places which would be likely to divert the water from the channel; and they recommend that when the commerce of the river would authorize the expenditure, these temporary arrangements should be replaced with permanent artificial banks.

With the results of these two plans before me, which are so plainly visible on the river, and a careful professional study of it, particularly of the valuable map of the river made by the officers of the Coast Survey in 1854, I had no difficulty in projecting a plan for the improvement, which, if carried out faithfully, will, I am satisfied, give us at an early day all the depth of navigation needed for the business of the city.

I will not trouble you with any of the details of this plan, for you have seen enough of them to enable you to form an intelligent opinion of them; I will merely state that my plan is to straighten the river and ease the curves or bends where it can be done to advantage and with not too great an expense, and to confine it for the whole distance, from Petersburg to the Point of Rocks, by artificial banks, wherever they are needed, to one channel, expanding regularly in width from 200 to 500 feet, so as to give ample room both for the freshets and flow of the tides.

To make this plan as perfect as I conceive it could be made, I did not hesitate to abandon the present channel of the river almost entirely, for with the construction of about a mile of new channel I shall shorten the river nearly half a mile and conduct it into the old south channel, which, no doubt, was anciently the true channel of the river. In the old works it had been shut off repeatedly, but never perfectly, and when I took charge of the improvement fully half the flow of the downward water passed into it. One has only to see this beautiful body of water, with its comparative straightness, and bold southern shore, to be satisfied that with little expense it can be made the finest part of the river. The north shore or bank of this channel, and everywhere else where the bank is needed to confine the river, will be made of the material dredged from the river to obtain the necessary depth of water.

I am satisfied, from the experience of this river, and from results shown in other rivers, that the increased impetus which this shortening and narrowing of the river and confining it to one channel must give to the freshets and tidal flow, will keep the bed of the river so scoured out that very little dredging will be required, except to strengthen the banks or make the navigation deeper.

On first of March last, as soon as the money for the works was secured, we let to contract all the piling timber, and driving of piles, and the blasting of the rock in Stein's upper cut. We also contracted for a dredge, as the bids we received for dredging were all too high. We had an old dredge, which we immediately set to work on the new cut through Puddledock, and we commenced driving piles as soon as the contractors could start their pile-drivers. We also hired a dredge, and in May last the new one was received and put to work.

We had purchased a new ten-horse engine and pump for the purpose of keeping the water down in Stein's cut while the rock is blasting, and have built some lighters and two large pontons, and fitted them up with railroad tracks and cars to land the material dredged out of the river. We have lately contracted for another dredge and steam-tug, which will be delivered by the end of the month.

The work done up to the first of this month is as follows:

All the piling-timber has been delivered and the contractors have driven and finished 10,200 feet of piling. This piling is driven wherever there is water, or very low places through which the current might be diverted, as a nucleus upon which to form the embankment. The dredges have made a single cut through Puddledock Swamp, 6,173 feet long, 30 feet wide, and 8 feet deep. The greater part of this swamp was covered with a dense growth of large trees, the stumps of which had to be blasted out before the dredges could start them.

Besides this work, the dredges have made a cut of 1,200 feet in length, and 10 feet deep, toward uncovering the rock in Stein's cut, and have raised to high water the embankment necessary to protect 2,100 running feet of piling. A considerable amount of ditching and clearing has in the mean time been done by hand labor, most of which has been finished. About three-fifths of the pile-driving and the blasting the rock out of Stein's cut is all the work that remains to be done by contractors.

The principal, and, indeed, the only remaining important work to be done now is the dredging to make the embankment. I expect soon to be able to put three dredges to work on it. These dredges will lift an average of 1,500 cubic yards a day.

I have added to this report an account of the expenditures we have made on the work from the first of March last to the end of this month, and also my estimate of the whole cost of making so much of the improvement as will give us 12 feet water.

As a part of this report I present you with a tracing from the map showing the old channel and the new one I am making. Also an enlarged map and profile of the rock-cutting in Stein's cut, and a sheet containing a plan of the pontons for landing the dredged material, and cross-sections, showing the different modes of driving piles.

Hoping these papers and this report will give you all the information you need in regard to our work,

I have the honor to be your obedient servant,

H. D. BIRD,
Chief Engineer Lower Appomattox Company.

Col. W. P. CRAIGHILL,
Chief Engineer in charge of Government Surveys of James River, &c.

Statement of expenditures made by the Lower Appomattox Company on the new improvement of the river from March 1, 1870, to September 1, 1870, six months.

For machinery, materials on hand, and for land:	
Paid for new dredge	$15,656 00
Paid for two pontoons	7,011 04
Paid for two lighters	255 12
Paid for engine and pump to drain Stein's cut	1,615 00
Paid for wheelbarrows and tools	395 00
Paid for piling-timber on hand	14,209 08
Paid for wood	410 00
Paid for land damages	1,300 00
For work done:	
Paid for piling material used	11,645 90
Paid for driving piles	6,793 50
Paid for running dredges	6,509 84
Paid for work in Puddledock cut	3,860 90
Paid for work in Stein's cut	345 61
Paid for engineering expenses	3,381 91
Paid for contingent expenses	1,798 61
Total expenditure	75,186 70

Estimate of the cost of improving the Appomattox River to obtain a depth of 12 feet navigation made August 20, 1869.

For improvement in harbor of Petersburg	$9,248 50
Making new channel through Stein's cut	13,805 00
Making new channel through Puddledock	9,615 00
Piling materials and driving	38,700 00
Dredging-machinery and dredging	70,800 00
Riprapping	3,608 00
Engineering expenses and superintending	11,500 00
Contingencies, 10 per cent	15,727 65
Total estimate	173,004 15

N. B.—This estimate contains no provision for building the docks laid down on the map. There is an additional estimate for the dock on the south side. It will cost $33,088.50. Neither this dock nor the one on the north side will, of course, be needed until they are required by the trade. I laid them down on the map to complete the plan of improvement. I got two miles of wharfage in a length of half a mile, and a width of less than a quarter of a mile. The docks can be so arranged with suitable gates that they can be scoured out during any freshet by plashing the water through them. I omitted to state above that the worst streams entering into the river are those on the north side, Oldtown Run and Swift Creek, neither of which run into the new channel. The artificial bank on the north side will not have a stream running through it. On the south side the only streams of importance will be conducted into the river at such an acute angle as not to create eddies.

U 18.

IMPROVEMENT OF THE SOUTH BRANCH OF THE ELIZABETH RIVER, VIRGINIA.

The improvement proposed was the excavation of a channel, 60 feet wide at the bottom and 7½ feet deep at mean low-water, through the numerous bars and shoals between the lock of the Albemarle and Chesapeake Canal and Deep Creek three and a half miles below; also, the cutting off of one or two points where the bends in the river were very abrupt. Such a channel has been excavated nearly continuously for

5,400 yards from the lock down, and below that distance at intervals through the shoals as far as the funds would allow. There are still two shoals known as Nicaraugua Bar and the Deep Creek Bar, through which dredging is required before the work already done will be available to the full extent.

The work has been done under two contracts. The first was with Mr. G. H. Ferris, of Brooklyn, who removed 29,500 cubic yards of material from the river between October 13 and December 24, 1873. The second was with Mr. Marshall Parks, who, between March 4 and June 18, 1874, removed 11,855 cubic yards, of which 7,118 cubic yards were deposited on the banks of the river at various points, and 4,737 yards were thrown off lighters in coves where there was little danger of its return into the channel. The matter removed by Mr. Ferris was also dumped in coves.

The work will be continued, as far as funds are available, toward completion during the year ending June 30, 1875, in the use of the appropriation of $10,000 of June 23, 1874.

The improvement affects a large shipping interest in Norfolk, Baltimore, and North Carolina, as at present a number of vessels in the river, in passing to and from the canal, are compelled at times to wait several hours for a suitable tide. When the work is once completed by the United States there will be small annual repairs necessary for the channel, which, it is supposed, will be made by the company, of whose canal the river is the actual extension to Norfolk.

The river is in the collection-district of Norfolk, which is the nearest port of entry.

From the report of Mr. Marshall Parks, president of the canal company, for the year ending September 30, 1873, it appears that the number of vessels passing through the canal for that year was 5,618 of all kinds, of which 2,075 were steamers, nearly all of greater draught of water than could be taken through the river at low tide. As the vessels of other classes were, to a great extent, dependent upon the steamers for towing, they also were subject to detention. This canal is somewhat peculiar in character, having but a single lock, which is one of the finest in the country, and, having no towing-path, steam is the only artificial motor used upon it. The communication, of which the Elizabeth River and this canal are parts, is a highly important one.

This improvement was estimated to cost $25,000. The appropriations by Congress have been $15,000 March 3, 1873, and $10,000 June 23, 1874; total, $25,000.

Some of the work by contract has cost considerably more than was expected, owing to the unusual difficulties found in disposing of the material removed by the dredges, and the inability to procure and control reliable labor in that section of country, amounting at times nearly to a suspension of work.

What has been stated and the non-continuity of operations, which always adds to expense, make it necessary to ask for $5,000 for the year ending June 30, 1876.

Financial statement.

Balance in Treasury of United States July 1, 1873	$15,000 00
Deduct amount expended in fiscal year 1872–'73	20 00
Amount appropriated by act approved June 23, 1874	10,000 00
Amount expended during the fiscal year ending June 30, 1874	14,281 73
Amount available July 1, 1874	10,698 27
Amount required for the fiscal year ending June 30, 1876	5,000 00

Proposals opened 12.5 *o'clock p. m., January* 10, 1874.

No.	Name.	Address.	Kind and number of machines.	Time.		Price per cubic yard.	Remarks.
				Commence.	Complete.		
1	Morris & Cumings	New York City	1 Clam-shell	Feb. 1, 1874	Apr. 1, 1874	$0 45	
2	Marshall Parks	Norfolk		Feb. 15, 1874	June 15, 1874	43	Will deposit on marshes.

Contract, Marshall Parks, at 43 cents per cubic yard.

COMMERCIAL STATISTICS.

CUSTOM-HOUSE, NORFOLK, VA.,
Collector's Office, July 18, 1874.

SIR: Your communication of the 14th instant, relative to forwarding such information to your office that would be of valuable assistance to you in your annual report, is received.

In reply, I have the honor to submit the following information, viz:

1st. Amount of revenue collected at this port during the fiscal year ending June 30, 1874, $32,000.

2d. Amount of exports during the fiscal year ending June 30, 1874, $1,830,036.

3d. Amount of tonnage, number of vessels, and crew entered coastwise during the fiscal year ending June 30, 1874:

Class.	Tonnage.	Crew.	No.
ENTERED.			
Side-wheel steamers	816,008	23,405	713
Propeller steamers	403,471	10,345	555
Barks	2,508	45	5
Brigs	5,076	151	17
Schooners	11,886	582	129
Sloops	35	8	2
CLEARED.	1,238,984	34,536	1,421
Side-wheel steamers	792,055	20,739	687
Propeller steamers	348,902	9,207	499
Brigs	707	14	2
Schooners	6,748	341	76
Sloops	33	3	1
	1,148,445	30,304	1,265

4th. Amount of tonnage, number of vessels, and crew of American vessels entered from foreign ports during the same period:

Entered.—Tonnage, 1,162; crew, 51; number, 6.
Cleared.—Tonnage, 13,474; crew, 375; number, 36.

Foreign vessels for same period:

Entered.—Tonnage, 20,389; crew, 808; number, 54.
Cleared.—Tonnage, 25,193; crew, 649; number, 48.

5th. In my opinion there would be benefited by the improvement of the harbor at this port a vast quantity of coastwise shipping, such as the Old Dominion Steamship Company steamers, Baltimore Steam Packet Company, Boston Line of Steamers, Philadelphia, Richmond, Washington, Edenton, and several other lines of steamers.

There would be a great amount of advantage and a vast deal of benefit in favor of the Allan Line of English steamers; also the San Antonio Line, of which several of its steamers touch at this port every month. The present indications at this port, and the calculations which have been and are now being made by the different merchants for the purpose of the shipment of cotton, are demonstrative of great progress.

The amount of cotton exported to foreign countries the past fiscal year, as follows: 24,819 bales, amounting to 11,405,911 pounds, shows an enormous increase since the opening of the custom-house in 1864; and there are in progress of erection three immense cotton-presses, together with the one that has been completed for the past six months, which will add materially to the cotton business at this port.

The intended improvements to the harbor here would be of great benefit to the large vessels, drawing considerable water, which enter this port for the purpose of being laden with merchandise of various kinds.

It is the intention of the cotton merchants of this city to ship a great quantity of cotton during the coming fall, thereby enlarging the commercial statistics of this locality.

Hoping that the above information may be of much benefit and advantage for your annual report,

I am, very respectfully, your obedient servant,

CHAS. E. GETTSLICH,
Deputy Collector.

Major W. P. CRAIGHILL,
Corps of Engineers. U. S. A.

Letter of President Albemarle and Chesapeake Canal Company.

OFFICE OF THE ALBEMARLE AND CHESAPEAKE CANAL COMPANY,
Norfolk, Va., July 25, 1874.

SIR: In reply to your letter respecting the southern branch of the Elizabeth River, I would state that the excavation in the natural channel, executed under your direction during the past season, has greatly improved the navigation, and it is confidently expected that when the work is fully completed as designed, for which Congress has made a partial appropriation, vessels drawing less than eight feet of water will be able to arrive and leave the lock of the canal of this company at all stages of the tide.

The Albemarle and Chesapeake Canal Company have expended several thousand dollars in the improvement of the natural channels leading to their canals, and I need only call the attention of the public to the importance of this improvement to the "commerce between the States" by stating the traffic through the canal for the past year. By the printed report of the company for the fiscal year ending September 30, 1873, five thousand seven hundred and seventy vessels, consisting of steamers, schooners, sloops, barges, lighters, boats, and rafts, have passed through, and during the nine subsequent months, ending June 30, 1874, there have passed four thousand three hundred and eighty-four vessels of all classes.

I would also mention that such has been the progress of using steam on the Albemarle and Chesapeake Canal (which was designed and constructed expressly for this purpose) that sixty-four steamers have been running on the canal during the present year, and since the opening of navigation by this company, in 1861, fifty thousand one hundred and eighty-three vessels, all of which have been propelled by steam or towed by steamers, have passed through this new canal and inland line, from New York, Philadelphia, Baltimore, and Norfolk, to the several ports in North Carolina, to Charleston, Savannah, and other southern ports.

I cannot close this letter without expressing the hope that Congress will make additional appropriations to improve the inland waters from the North to the South, and that the few links required to make the inland navigation from Massachusetts to Florida may be completed at an early day.

More than half a century ago the great importance of this line of intercommunication, considered in a national point of view, received an official recognition in a report of the Hon. Albert Gallatin, the then Secretary of the Treasury. He recommended the line adopted by this company as the shortest and cheapest route for a line of inland navigation between the North and South, which, together with the Chesapeake and Delaware and the Delaware and Raritan Canals, completes a chain of inland navigation from New York southward, a distance of about 600 miles, avoiding the dangers of Hatteras and the coast of North Carolina.

Respectfully, your obedient servant,

MARSHALL PARKS, *President.*

Col. W. P. CRAIGHILL,
Corps of Engineers, U. S. A.

Comparative statement of tolls and towing received during each year from September 30, 1865, to September 30, 1873, inclusive.

Year.	Tolls.	Towing.	Total.
Year ending September 30, 1866	$41,346 54	$9,241 75	$50,588 29
Year ending September 30, 1867	48,682 01	10,810 83	59,492 84
Year ending September 30, 1868	47,872 43	10,398 14	58,270 57
Year ending September 30, 1869	45,073 60	11,452 26	56,525 86
Year ending September 30, 1870	47,662 56	10,567 61	58,230 17
Year ending September 30, 1871	55,778 72	8,806 77	64,585 59
Year ending September 30, 1872	60,846 64	10,251 58	71,098 22
Year ending September 30, 1873	73,251 88	11,587 16	84,839 04
Total	420,514 38	83,116 10	503,630 48

Report of number and class of vessels passing through the Albemarle and Chesapeake Canal for the fiscal year ending September 30, 1873.

Year.	Month.	Steamers.	Schooners.	Sloops.	Barges.	Lighters.	Boats.	Rafts.	Total.
1872	October	162	81	33	20	71	39	5	411
1872	November	163	101	47	23	73	37	9	453
1872	December	105	87	38	13	41	13	1	298
1873	January	167	128	71	20	72	11	7	476
1873	February	132	131	60	10	69	17	6	425
1873	March	185	143	87	16	75	48	2	556
1873	April	182	147	64	21	89	31	11	545
1873	May	195	130	44	11	102	29	18	529
1873	June	193	118	39	23	86	21	20	500
1873	July	195	144	45	26	70	99	22	601
1873	August	210	104	39	23	65	83	32	556
1873	September	186	66	25	19	73	32	19	420
	Total	2,075	1,380	592	225	886	460	152	5,770
	North	1,030	699	298	140	490	234	152	3,033
	South	1,045	681	294	95	396	226	.....	2,737
	Total	2,075	1,380	592	225	886	460	152	5,770

Number and class of vessels passing through the Albemarle and Chesapeake Canal from September 30, 1860, to September 30, 1873.

Year.	Steamers.	Schooners.	Sloops.	Barges.	Lighters.	Boats.	Rafts.	Total.
1861	671	1,139	74	153	300	179	8	2,524
1862	453	192	88	69	275	188	.....	1,265
1863	377	62	71	16	292	125	.....	950
1864	953	24	15	124	96	174	5	1,391
1865	1,300	266	190	122	79	602	3	2,562
1866	1,062	739	302	256	338	921	18	3,636
1867	1,112	907	358	313	763	761	29	4,243
1868	1,093	944	442	381	778	1,066	26	4,730
1869	1,093	752	398	297	950	1,077	36	4,638
1870	1,487	859	437	167	911	486	35	4,382
1871	1,656	944	555	183	1,030	483	49	4,900
1872	1,667	1,070	523	158	752	553	85	4,808
1873	2,075	1,380	592	225	886	460	152	5,770
Total	15,034	9,285	4,045	2,464	7,450	7,075	446	45,799

NORFOLK, VA., *September 30, 1873.*

List of steamers navigating the Albemarle and Chesapeake Canal, number of passages, and amount of tolls paid, for the fiscal year ending September 30, 1873.

Names.	Passages.	Tolls.	Names.	Passages.	Tolls.
Astoria	85	$3,729 76	Juniper and raft	32	$493 53
Alpine	17	45 29	J. W. Allison	1	44 80
Arago, (U. S)	2	28 00	J. B. Woodward	15	141 00
Annie Wood	1	3 75	Louisa	49	3,179 39
Benj. Winder	27	866 05	L. G. Cannon	78	2,106 14
Brooklyn	27	93 34	Lucy	42	1,380 36
Cygnet	227	2,340 05	Lumberman and raft	78	814 30
Chowan, (company's tug)	159	.....	Lynnhaven	54	996 53
Croatan, (company's tug)	148	.....	Laura and raft	52	2,415 68
Currituck	46	1,188 20	Mollie Wentz	25	579 87
Clarion and raft	61	1,495 79	Nettie and raft	28	2,147 97
Commerce	38	1,532 76	N. W. A. Cobb	9	.....
Dixie	1	4 20	North Carolina	42	687 43
E. Ludlow and barge	34	1,334 52	Olive	101	2,300 56
E. B. Lane and barge	45	1,307 27	Rotary	63	1,123 18
E. Chamberlaine	18	323 67	Raleigh	9	362 73
Elizabeth City	11	135 31	R. T. Waters and raft	95	3,472 80
Erie Enterprise	9	275 80	Sparkle	24	397 43
Emma Dunn	4	55 29	Scow	1	29 10
E. W. Molyneaux and raft	39	453 20	San Antonia	1	64 80
E. Payson	1	46 50	S. J. Flemming	2	143 17
Estelle	15	69 05	Tulip, (U. S)	8	436 80
E. A. Stephens, (U. S)	1	39 00	Thos. E. Cahill	15	719 26
Guiding Star	2	20 99	Thos. Jefferson	12	111 51
Hackensack	34	1,291 09	United	18	929 61
Heliotrope, (U. S)	2	120 00	Uncle Knoff, (U. S)	1	41 80
Hero and raft	2	97 00	W. G. Oler	6	328 34
Harbinger	1	13 23	Wm. Nuci	1	9 30
H. Smith	2	22 15	Wm. Gates	3	46 92
Isis	1	29 30	W. H. Seward, (U. S)	1	80 00
Ida and raft	32	1,573 23	Winnepenny and barges	1	65 50
I. D. Coleman	19	602 62			
Joe Townsend	87	748 51	Total	2,075	45,351 66

List of steamers passing through the Albemarle and Chesapeake Canal, and number of passages from October 1, 1873, to June 30, 1874.

Names.	Passages.	Names.	Passages.	Names.	Passages.
Astoria	60	Harbinger	5	Nettie	7
Alida	6	Helen Smith	2	Olive	75
Arago	2	Hackensack	17	Pamlico	3
Benj. Winder	16	Isis	2	Propeller	1
Belle Virginia	47	Ida	23	Rotary	22
Brooklyn	69	J. D. Coleman	31	Raleigh	77
Bloomsburg	2	J. M. Molyneaux	4	Ruggles	1
Cygnet	161	Jas. T. Eastmor	1	R. T. Waters	57
Chowan	130	J. B. Woodward	52	Silver Wave	17
Croatan	69	Juniper	52	Sparkle	22
Chester	2	Joe Townsend	50	Stanley	2
Commerce	35	Lynnhaven	40	Sea Weed	3
Clarion	16	L. G. Cannon	69	Lt. Fields	5
Currituck	33	Lumberman	39	Stephen	1
E. City	7	Laura	3	Tulip	4
E. Ludlow	20	Lausin	38	T. J. Cochran	30
Emma Dunn	4	Lucy	38	Tuchapoe	2
E. B. Lane	7	Mollie Wentz	24	United	14
Estelle	3	Mary C	9	Wm. Gates	3
E. W. Molyneaux	59	Mary E. Roberts	69	Zephyr	1
Erie Enterprise	2	May Flower	1		
Heliotrope	4	North Carolina	28	Total	1,699

Number and class of vessels passed through the Albemarle and Chesapeake Canal from October 1, 1873, to June 30, 1874.

Steamers	1,699
Schooners	1,134
Sloops	480
Barges	262
Lighters	556
Boats	159
Rafts	94
Total	4,384

U 19.

IMPROVEMENT OF NANSEMOND RIVER, VIRGINIA.

During the month of July, 1873, the snags and sunken trees in the bed of the river, and the overhanging trees and branches on its banks, which were obstructing navigation, were removed.

The construction of the proposed regulating and retaining dike was commenced August 6, and suspended January 13, 1874, when 2,156 linear feet of it had been completed.

During the months of October and November all the artificial obstructions in the channel-way of the river were removed by blasting, hoisting, and dredging. They consisted of the wrecks of a schooner and a sloop, and 41 piles near the Western Branch bar, and 19 piles in Lower Blockade, about four miles from the mouth of the river.

An examination of the bar at the Western Branch and its vicinity was made in April, 1874, and it was found that (owing to the contraction of the river-bed by the dike) the river had commenced cutting deeper the channel at the up-stream end of the bar.

Proposals for dredging were invited and a contract made with Messrs. Morris and Cumings, June 1, 1874.

The contractors commenced operations June 5, and it is expected that they will finish their contract about July 15. A channel 75 feet wide at bottom and 7 feet deep at mean low-water will then be available.

This work is located in the collection-district of Norfolk, which is the nearest port of entry. Amount of revenue collected at that place during last fiscal year, $32,000.

For further statistical data, reference is requested to report of Chief of Engineers for 1872, pages 725 and 726.

The estimate for the improvement of this river was $30,000. There have been appropriated by Congress $15;000 March 3, 1873, and $10,000 June 23, 1874—total, $25,000, leaving $5,000 to be appropriated to fill the estimate and complete the work.

Financial statement.

Balance in Treasury of United States July 1, 1873	$12,500 00
Amount in hands of officer, and subject to his check	2,087 30
Amount appropriated by act approved June 23, 1874	10,000 00
Amount expended during the fiscal year ending June 30, 1874	9,175 99
Amount available July 1, 1874	15,411 31
Amount required for the fiscal year ending June 30, 1876	5,000 00

Bids opened at 12 o'clock m. May 27, 1874.

Number.	Name.	Address.	Kind and number of machines.	Approximate daily amount of work expected.	Time.		Price per cubic yard.
					Begin.	Complete.	
				C.yds.			*Cts.*
1	E. W. Ferris	Brooklyn	1 Osgood	400	June 5, 1874	Aug. 1, 1874	27
2	Morris & Cumings's Dredging Company.	New York	1 Clam-shell		June 5, 1874	July 15, 1874	20
3	J. H. Teemyer & Co.	Baltimore	Osgood		June 22, 1874	Oct. 31, 1874	30
4	Curtis, Fobes & Co.	Portland, Me.	Clam-shell	2,000	June 15, 1874	Aug. 1, 1874	34
5	H. E. Culpepper	Portsmouth, Va	1 or more Osgood		June 20, 1874	Sept. 20, 1874	37

Contract: James Cummings, president Morris & Cumings's Dredging Company, at 20 cents per cubic yard.

U 20.

IMPROVEMENT OF THE ROANOKE RIVER BELOW WELDON, NORTH CAROLINA.

As was stated in the last annual report, a second snag-boat of larger size had been fitted up to be used in conjunction with the old one. This boat was towed up the river early in July, 1874, nearly to Weldon, to be ready to commence operations so soon as the river was in a favorable condition, which was not until September 25, owing to freshets. A succession of these had caused much delay during the whole year.

The entire course of the river from the railroad bridge, one mile below Weldon to its mouth, a distance of about one hundred and thirty miles, has been carefully dragged, and there have been removed 47 bad snags, and 10 rafts of trees, timber, &c., which had lodged at different places. These rafts are generally caused by land-slides. A large number of overhanging trees, throughout the course passed over, have been cut down or trimmed, and as the land-slides are generally due to such trees, it is probable they may be fewer hereafter.

The cut-off known as the Devil's Gut, by which the distance between Jamesville and Williamston is reduced about six miles, an important saving, has been cleared out to within three miles of the lower end, the space passed over being the worst portion. The snag-boats were towed to the upper end of the gut and operations commenced there. Eight very large snags have been taken out. The masses of trees and rafts which had lodged made the passage impossible for any but a small boat. By the removal of these, and the cutting down of overhanging trees, a way is cleared for small steamers to pass through.

In January, 1874, the snag-boats assisted in raising a tug-boat which was sunk in the river by accident, and otherwise would probably have been totally lost, as well as become seriously hurtful to the regimen of the stream.

Under a contract for the purpose, Mr. Foote has removed from the bed of the river, or so broken up that the remains no longer obstruct navigation, a light-boat at Broad Creek, a steamboat near Jamesville, and a light-boat and three schooners at Willow Bend. These were the last wrecks in the river which impeded its navigation.

Mr. Foote has also done some work under his contract for removing rock near Weldon, but has been very much retarded by freshets. All the necessary blasting is reported as done, but the actual removal is not yet completed. It is expected that he will finish his work this summer.

The operations have, on the whole, been satisfactory, although much interrupted during high stages in the river. The navigation is materially improved. It is believed very few snags have been passed over. A few could not be taken out with the machinery available. These should be removed by blasting. It is expected that the snag-boats will again pass over the entire length of the river below Weldon.

The improvement of this river is of much interest to the whole of the adjacent country, for which it is the only outlet. This is an exceedingly fertile country, from which its products, cotton, lumber, and shingles, are shipped in large quantities.

The river is situated in the collection-district of Edenton, which is the nearest port of entry. The nearest light-house is the Roanoke River light.

In a report of December 5, 1871, printed in annual report for 1872, an

estimate was presented of $270,000 for giving 5 feet at low-water from Weldon down.

The appropriations by Congress have been $20,000 March 3, 1871, $10,000 June 10, 1872, $10,000 March 3, 1873, $5,000 June 23, 1874; total, $45,000.

On the 30th June, 1874, the sum of $15,227.94 was available for this river. Up to this time operations have been confined to removing wrecks, snags, rafts, overhanging trees, sunken logs, and some rocks near Weldon, which, except the last, should be continued. Unless it is determined to enter systematically upon the improvement of the river in the attainment of a low-water depth of 5 feet, no appropriation is needed for year ending June 30, 1876. If that work is to be carried out, the sum of $100,000 should be provided for the first year.

A report was made on the Roanoke River, dated January 17, 1871, which was omitted from the annual report for that year. It is worth printing, and is now appended hereto as a part of the history of the improvement.

A letter from the collector of customs at Edenton, N. C., dated August 25, 1874, is also appended hereto.

Financial statement.

Balance in Treasury of United States July 1, 1873	$20,000 00
Amount in hands of officer and subject to his check	4,073 41
Amount appropriated by act approved June 23, 1874	5,000 00
Amount expended during the fiscal year ending June 30, 1874	13,862 22
Amount available July 1, 1874	15,227 94

Report of January 17, 1871.

UNITED STATES ENGINEER OFFICE,
Baltimore, Md., January 17, 1871.

GENERAL: It is now apparent that it will be impossible for me to make a report on the Roanoke River (such as I wish to submit) in time for its consideration by you in less than a month from this date, and it seems proper that the cause of this delay should be stated, and a preliminary report made at once.

It will be recollected that authority for the survey was not given by Congress until late in the summer of 1870. The annual unhealthy season of the country through which the Roanoke flows had already begun. It proved to be more unhealthy than usual. It was impossible for me to make the examination of the river in person, other duties preventing. I was advised that it would be dangerous for unacclimated persons to spend even a single night upon the river, much less to attempt a continued survey or examination of it, until the malarious season should be ended under the influence of frost. Suitable persons, who were acclimated, could not be procured.

In the mean time a partial examination was made by myself and assistants, and considerable information was collected by personal interviews and written correspondence with those who claimed to know the river well.

As soon as the weather permitted a party was placed upon the river, and the survey from Weldon down commenced, under direction of Mr.

George H. Elliott, the efficient civil assistant for several years past at Fort Monroe.

The survey progressed well, when it was interrupted by the formation of ice in the river in December, a most unusual occurrence in that locality.

I have to-day had a letter from Mr. Elliott, dated 12th instant, in which he states that the survey cannot be completed before the early part of next month. The report will be rendered as soon after the 1st of February as practicable, but in all probability not before the adjournment of the present session of Congress. I regret this fact very much.

That part of the river above Weldon has been the subject of consideration and report by several local engineers in years gone by, with a view to determining the proper means of passing the rapids between the successive pools into which that part of the river is divided.

The Roanoke River, for a considerable part of its course, and the Dan and Staunton Rivers, which by their union form the Roanoke, flow through a country of much fertility, producing tobacco, cotton, wheat, corn, timber, hides, &c. The fisheries at the mouth of the Roanoke are also very valuable.

Steamers from Norfolk plying through the canals and sound carry to that city the produce of the Roanoke country, from Hill's Ferry to the mouth of the river. There is another line of steamers on the river, between Hill's Ferry and Weldon, which is a feeder to the railroad from Weldon to Portsmouth.

At and near Weldon are found the principal falls in the river, which, although making a formidable obstacle to the navigation of the river, afford a very fine water-power for manufacturing purposes, in close proximity to the raw material, cotton; in a country richly productive in provisions; with feed cheap and near at hand; with rapid means of communication with all parts of the country, and with easy access to the sea, through the ports of Richmond, Norfolk, and Petersburg, within short distances.

Above Weldon the falls are turned by a canal. Above the canal the navigation of the Roanoke and its tributaries has been carried on by means of bateaux. These boats are about 50 feet in length, from 5 to 8 feet broad, with a carrying-capacity of about six tons, and a draught of water of about 15 or 18 inches when loaded. The trade carried on by these boats was in former years extensive, important, and highly valuable. It has greatly fallen off since the introduction of railroads through the country, which afford a much more rapid means of transport of the products of the country to market and of return freights. The rates of freight on the railroads are of course higher, and the people are very anxious for such an improvement in the navigation of the river above Weldon as will allow the advantageous use of light-draught steamers.

In 1823 Mr. Isaac Briggs estimated that a sufficient improvement of the Upper Roanoke at that time could be made for $25,000. His report on the Roanoke and its tributaries is quite elaborate.

Mr. John Couty's estimate of 1838, for improving the Roanoke for more extended uses, by lock and dam navigation, amounted to $350,000.

It is the opinion of an experienced civil engineer, who knows the present condition of the Upper Roanoke, that a depth of two feet could be obtained at moderate cost.

I am not now prepared to submit a project or an estimate for the improvement of the Roanoke above Weldon, neither the time nor money at my disposal having been sufficient to enable such an examination to be made as would give the data for an estimate. A considerable sum

of money has been expended on that portion of the river, under the direction of a company holding a charter, as I am informed, from the States of North Carolina and Virginia, but I have been unable to learn its amount, or whether the expenditure proved remunerative.

Several small vessels were sunk during the war in the Lower Roanoke, which should be removed.

Dredging will be needed in several places, with perhaps the removal of some overhanging and fallen trees; and snags require to be cut away.

When Mr. Elliott has completed his survey, plans and estimates for the improvement of the river will be submitted. Enough is already known to indicate that the sum of $40,000 can be advantageously expended upon the Roanoke in the next fiscal year.

I send herewith papers, &c., as follows:

1. Report (1823) of Isaac Briggs, on Roanoke, Dan, and Staunton Rivers.
2. Report (1836) of Thomas Blanchard, on navigation of Upper Roanoke.
3. Report (1838) of John Couty, on Upper Roanoke.
4. Article from Roanoke News, of January 7, 1869, published at Weldon, relative to navigation of the river, &c.
5. Communication of October 14, 1870, from Mr. Charles G. Manning, collector of the district in which the Roanoke River is situated.
6. Consolidated statement of tolls collected at Gaston, from October, 1845, to October, 1854.
7. Detailed and consolidated statement of tolls and articles subjected to toll at Gaston from October 1, 1844, to October 1, 1851.
8. Map of part of the town of Weldon, showing location of canal, basin, &c., December 11, 1868.
9. Map of canal in plan and profile, and of Roanoke River, &c., near Weldon, March, 1860.
10. Map showing course of Roanoke River, from its mouth to some distance above Gaston.
11. Map in two sheets, showing course of Roanoke above Williamston, and of its tributaries, the Dan and Staunton Rivers.

Very respectfully, your obedient servant,

WM. P. CRAIGHILL,
Major of Engineers.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

Commercial statistics.

CUSTOM-HOUSE, EDENTON, N. C.,
Collector's Office, August 25, 1874.

SIR: Your letter of the 14th of July came duly to hand and contents noticed. The delay in answering your inquiries is owing to the tardiness of the parties to whom I wrote some weeks ago in giving me the information desired. I now furnish only partial returns. Time is passing rapidly, and, fearing you might conclude I had neglected your letter, I deemed it better to furnish you at once with all the information it has been possible for me to derive from the various sources to which I have applied.

I have the honor to report the following:

1st. The collection-district is Albemarle. 2d. Amount of revenue collected during the fiscal year ending 30th June, 1874, on foreign importations, is $265.73. Amount marine-hospital dues collected during same period is $597.69.

There is no port of entry excepting the port of Edenton for vessels engaged in the foreign trade. There are several ports of entry and delivery below Edenton and above Edenton, on the Roanoke River and tributaries, for vessels in the coastwise trade. Below Edenton, viz: Columbia, Elizabeth City, Coinjock, and Crawford. Above Edenton, viz: Plymouth, Windsor, Jamesville, Williamston, Hamilton, Hill's Ferry, and others.

The amount of commerce and navigation on the Roanoke River and its tributaries is as follows:

The amount of imports from northern ports landed at Plymouth and other places on the Roanoke River and its tributaries, including fertilizers, (value of $30,000,) about $850,000. Amount of products, including timber of all kinds, cotton, and other products, and the fisheries, $3,500,000. Total tonnage employed in carrying on above trade, about 200,000 tons.

The improvements already made on the Roanoke River have been of great benefit to its commerce and navigation, and further improvements are still needed, especially on the Upper Roanoke below Halifax, and also on some of its tributaries, viz: Gardner's Creek, one mile from Jamesville, and the thoroughfare leading from the Roanoke to Cashie River, four miles above Plymouth. I have no doubt these improvements, if made, will increase the commerce and conveniences of navigation in proportion to the extent of the improvements made.

Edenton Bay and Harbor and the mouth of Mackay's Creek, of which surveys have been made, are especially recommended to your attention. If the improvements were made which were reported last year, the conveniences of trade and navigation of said places would be greatly facilitated, and it is believed the amount of products of the sections contiguous thereto would be increased in like proportion.

The obstructions have so greatly increased, that masters and agents of steam and sail vessels drawing more than 7 feet of water frequently object to bringing to or taking freight from these places. The trade of Edenton alone is estimated to be about $650,000. All of the estimates herein made are believed to be under the actual value of the products of the sections lying on and near the Roanoke River and its tributaries.

I would therefore, respectfully recommend that the improvements be made to these places, in conformity with the surveys and estimates made therefor last year.

Very respectfully, your obedient servant,

CHAS. G. MANNING,
Collector District of Albemarle, Edenton, N. C.

Maj. WM. P. CRAIGHILL,
United States Engineer Corps.

U 21.

IMPROVEMENT OF THE CAPE FEAR RIVER, NORTH CAROLINA.

The report is appended hereto of Capt. C. B. Phillips, Corps of Engineers, who has had the immediate supervision of this interesting and important work. He deserves praise for the energy and faithfulness which he has manifested, and has my thanks therefor. Reference to that report is requested for details.

The sand continues to accumulate with gratifying rapidity near the closing work between Smith's and Zeke's Islands, and the two will soon form but one. Numerous shoals are growing horizontally and vertically, and thus gradually emerging from the water.

The indications increase of the opening of a new and straighter channel through the Bald Head entrance, or rather of the re-opening of the old and natural channel, which deteriorated so rapidly after the breaking through of the New Inlet. There are ample grounds for the belief that by steadily carrying forward the work the New Inlet will be entirely closed in a reasonable time, chiefly by the agency of the winds and waves, and the river be practically restored to its condition of a century ago, when New Inlet had no existence, and the old mouth of the river had one of the finest entrances on the South Atlantic Coast. The strong and increasing probabilities of attaining such a result, which is of national importance, induce me to renew the recommendation made in previous reports, that funds be liberally provided for this work. It is a case in which liberality is true economy, if the work of improvement is to be carried through.

As exhibiting my views as to further steps in the improvement, there is appended below a copy of the following communication on the subject:

UNITED STATES ENGINEER OFFICE,
Baltimore, Md., July 16, 1874.

GENERAL: Up to this time the operations for the improvement of the Cape Fear have been rather preliminary than direct in their bearing, though they have been of notable benefit to the river and to the commerce of Wilmington. Their object has been to diminish the outflow through New Inlet, with a proportional increase in the discharge through the old mouth of the river.

The closing work between Smith's and Zeke's Islands, $1\frac{1}{2}$ of a mile in length, necessarily had a great influence in the desired direction, which is observable in the increased depth on the old bar and the shoaling on that of New Inlet, the latter being now very much given up by the larger vessels trading to that port. The deflector from Federal Point, now extending to a length of 500 feet, has doubtless had a beneficial effect toward the same end. As this work is extended, its construction becomes slower, more difficult, and much more expensive. It is proposed to use none of the present appropriation upon it unless later in the fiscal year it may become expedient.

The dredging behind the Horseshoe Shoal, just opposite New Inlet, which has already received your approval, has the same object as those parts of the project already mentioned, as has also the operation of the suction-dredge on the Bald Head Bar.

The work on the Bald Head, as well as that behind the Horseshoe Shoal, are both, to some extent, experimental; but there are strong reasons for believing in the success of both, and the advantages of each, if successful, are so obvious and direct that both should be done, and now is the time for them.

The Bald Head Bar, formerly (before the opening of New Inlet) the best, has now about 10 feet on it at low-water, but there has been a gain of more than a foot since work was commenced there in the latter part of 1870. The outer bar of the western channel has about 14 feet on it at low-water, but the inner bar, called the "Rip," has only about 10 feet. The Bald Head entrance is much the most direct, and is not obstructed by a "rip" or inner bar. It is the natural mouth of the river, and, I am convinced, will ultimately, if the improvement is continued, become again the best and most used entrance. Hence, the suction-dredge will be worked there, and the "rip" of the western channel will be disregarded, at least for the present.

In ascending the river there is water enough until we reach the very curved and unstable channel around the Horseshoe Shoal, through which not more than 9 feet can be carried at low-water.

The dredging behind the Horseshoe will shorten and straighten the channel, while at the same time diverting a large volume of water from "New Inlet" and into its old and natural channel, which ran in the direction of the cut now proposed to be dredged to a depth of 9 feet at low-water, and 100 feet in width. If the result is favorable, and such a result is expected, the cut should be deepened at once to 12 feet at low-water, as we may suppose the suction-dredge will have attained at the same time a depth of 12 feet on the bar.

Vessels drawing about 11 feet at low-water, or 15 to 16 feet at high-water, would then be enabled to approach to within twelve miles of Wilmington, when they find another obstruction, called the "Logs," over which only about 9 feet at low-water can be carried. Thence to the city 12 feet at low-water can be taken. The statement that has been made above seems to indicate that the project for the improvement of the Cape Fear should now contemplate the attempt to get 12 feet at low-water as high as the city of Wilmington, which amounts to $16\frac{1}{2}$ or 17 at high-water. The operations of this year, and the available funds, should, in my judgment, be directed toward the attainment of that object. The estimate below has been prepared, under my direction, by Capt. C. B. Phillips, Corps of Engineers, having this object in view.

"*Estimate for the improvement of Cape Fear River, North Carolina, so as to secure (by dredging) 12 feet of water (at mean low-tide) to the city of Wilmington.*

"The various points at which dredging would be required to secure the above are as follows:

"1. Horseshoe Shoal, below New Inlet; dredging 385,586 cubic yards at 35 cents, for a channel 200 feet wide at bottom	$134,955 10
"2. At the 'Logs,' or obstructions opposite Campbell's Island, about eight miles below Wilmington; removing stumps and logs, $5\frac{1}{2}$ cuts at same rate of cost as the $1\frac{1}{2}$ cuts already completed; each cut 30 feet wide; total proposed width 200 feet	41,580 00
"3. At the shoal immediately below the 'Logs;' dredging 124,666 cubic yards at 35 cents, for a channel 200 feet wide at bottom	43,633 10

"4. At the shoal immediately above the upper jetty, about three miles below Wilmington; dredging 14,963 cubic yards at 35 cents, for a channel 200 feet wide at bottom $5,237 05

"5. On the bar at the mouth of the river; running suction-dredge, (per month,) $1,000.

"RECAPITULATION.

"At Horseshoe	$134,955 10
"At 'Logs'	41,580 00
"At shoal below 'Logs'	43,633 10
"At shoal above upper jetty	5,237 05
	225,405 25
"Add for contingencies, superintendence, &c	22,540 52
	247,945 77
"Add for suction-dredge, one year	12,000 00
"Total	259,945 77

"C. B. PHILLIPS,
"*Captain of Engineers, U. S. A.*

"BALTIMORE, *July* 1, 1874."

This is for a channel about 200 feet wide, and requires $260,000. I believe that with this sum of money *at once available* the object indicated above could be attained. It is proposed to work toward that object as far as the funds at command will permit, commencing with the dredging behind the Horseshoe and the work on the Bald Head Bar, arrangements for which are already in progress.

The long, narrow spit called Smith's Island will always need watching and protection at certain exposed points. One of these now demands an immediate expenditure of some $4,000 upon it. It is probable that $10,000 more will be required for other points during the fiscal year. It is believed that if the cut behind the Horseshoe be opened and enlarged, New Inlet would continue to shoal, and eventually would nearly close. No estimate is therefore submitted for a work to absolutely shut up that inlet, for it would be, I think, an unnecessary expenditure of money to attempt it *now*. It will be probably found expedient to hasten the closing of the inlet, and assist in maintaining the channel behind the Horseshoe, by prolonging the deflecting jetty from Federal Point; but that will not be in this fiscal year.

If you approve the views presented in this communication the operations of the year will proceed accordingly, special approval to be asked when any new step of importance is about to be taken.

The estimate of Captain Phillips amounts to	$260,000
The amount now available is	150,000
Difference	110,000
Add for use of suction-dredge one year, and repairs	15,000
Add for protection, &c., Smith's Island	15,000
Add for extension of jetty from Federal Point	60,000
Total	200,000

Very respectfully, your obedient servant,

WM. P. CRAIGHILL,
Major of Engineers.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

October 14, 1870, General J. H. Simpson made an estimate for a work to close the opening between Smith's and Zeke's Islands, amounting to $256,000. There was appropriated June 11, 1870, $100,000; March 3, 1871, $75,000; June 10, 1872, $100,000; March 3, 1873, $100,000; total, $375,000.

This sum was expended up to June 30, 1874, in the work for which General Simpson estimated, and within his estimate: For the deflecting jetty, 500 feet long from Federal Point, in removing obstructions at the "Logs," and in the purchase, fitting up, and working of the suction-dredge on the Bald Head Bar.

The estimate now presented contemplates giving 12 feet at low-water, or 16½ feet at high-water, as high up the river as Wilmington, a very

important gain of 3 feet. This estimate amounts to $260,000. The appropriation of June 23, 1874, having been $150,000, there remains to be still supplied to complete the estimate $110,000. Add $15,000 for use of suction-dredge one year, and repairs; $15,000 for protection of Smith's Island, &c., and we have the sum of $140,000 as necessary for the year ending June 30, 1876. There will be probably required also for extending the jetty from Federal Point, $60,000, a sum which should be available for year ending June 30, 1876.

Financial statement.

Balance in Treasury of United States July 1, 1873	$100,000 00
Deduct amount expended in fiscal year 1872-'73	9,063 32
Amount appropriated by act approved June 23, 1874	150,000 00
Amount expended during the fiscal year ending June 30, 1874	92,935 13
Amount available July 1, 1874	147,951 55
Amount required for the fiscal year ending June 30, 1876	200,000 00

Report of Capt. Charles B. Phillips, Corps of Engineers.

UNITED STATES ENGINEER OFFICE,
Baltimore, Md., July 1, 1874.

MAJOR: I have the honor to submit herewith the following report of operations at the improvement of the Cape Fear River, North Carolina, during the fiscal year ending June 30, 1874:

At the date of the last annual report the work for the closing of the space between Smith's and Zeke's Islands had just been completed, and preparations had been made for commencing a jetty or deflector at Federal Point, on the northern shore of New Inlet.

A board of engineers, in its final report to the Chief of Engineers in December, 1872, recommended the construction of such a deflector, and in July following the work was commenced, in accordance with a project submitted to and approved by the Chief of Engineers, for the expenditure of the appropriation then available.

The deflector consists of crib-work, loaded with stone, and built to high-water mark, and takes from Federal Point a general southwest direction, following the line of shoals.

The construction of this deflector to a length of 500 feet has constituted the principal feature of the work on this river during the year.

A small force (averaging about four men) has been kept at the old work between Smith's and Zeke's Islands, engaged in making such slight repairs as were necessary; in filling and sinking sand-bags about the work; and in attending generally to the protection of the old work and the adjacent beaches.

In December last, it having been determined not to proceed at present with the new work at Federal Point to a greater length than 500 feet, a project for the expenditure of the balance available was submitted to the Chief of Engineers, and by him approved. (December 10.)

The project contemplated an attempt to remove the so-called "logs" or obstructions immediately above Campbell's Island, and about eight miles below the city of Wilmington.

Accordingly, a large dredge-boat, fitted up with grappling-apparatus, was chartered and, proceeding to the Cape Fear River, was engaged continuously at this point, from the 2d of March until the 11th of April, in removing stumps and logs from the channel of the river.

The above-mentioned project also contemplated the purchase of a steamer and her subsequent fitting-out as a suction-dredge, to work at the mouth of the Cape Fear principally at the Eastern or Bald Head Channel.

A propeller of 145 tons burden was purchased and fitted out, as stated above, her dredging-apparatus consisting of a 9-inch centrifugal pump, driven by a double oscillating engine (10-inch cylinders) with connecting suction and discharge pipes, and with sand-bins on the main-deck, of an aggregate capacity of about 40 cubic yards.

The suction-dredge commenced work on the 6th of April, at the Bald Head channel; but before a fair trial could be made of her capabilities she was called off, April 11, to assist in towing the grapple-dredge north. She has not yet returned to her own station.

During the month of May a survey was made of the shores adjacent to New Inlet,

including the new work at Federal Point, the old work between Smith's and Zeke's Islands, and the beach and shoals which have accumulated in the vicinity.

A coast survey party has also made a re-survey of the Bald Head Channel at the old mouth of the river, being engaged during portions of the months of May and June last.

RESULTS OF THE WORK FOR THE YEAR.

The sand has continued to accumulate in immense quantities about the old work between the islands, particularly on the outer side.

The shoals have increased in number and dimensions, and the two islands are nearly united by an almost continuous beach, which is constantly becoming higher and stronger.

As the new work has progressed out from Federal Point, the beach has followed until at present nearly one-third of the length of the crib-work is covered to high-water mark with sand.

This structure, independently of its service as a deflector of the currents, has done much to strengthen Federal Point.

As the work progressed, a very serious deepening occurred in advance of the line of cribs, the outer crib having been sunk in 20 feet of water, where originally there was but 6 feet.

This deepening, and consequent settling of the cribs, was checked to a certain extent, by the liberal use of brush loaded with stone, and sunk at the end and sides of the work.

The effects of the new work at points more remote from it are, to a certain extent, matters of conjecture. Changes have taken place at points below New Inlet, which perhaps may mainly be attributed to the influence of the Federal Point work.

Among the sechanges may be cited the remarkable growth of Zeke's Island during the year.

Before the new work was commenced, the island was growing rapidly in an easterly direction, and as stated in the last annual report was evidently restoring the old shore-line which it possessed before the breaks between the islands; this is due, no doubt, to the influence of the old work. During the past year, however, not only has this growth continued, but the island has also grown toward the north and west, thus contracting somewhat the width of New Inlet. It had been anticipated that the work might cause an abrasion at this point, rather than have the contrary effect.

A considerable abrasion has occurred at the most northeasterly point of Smith's Island, which it seems probable is due to the change of currents in New Inlet caused by the new work. Some apprehension has been felt that this abrasion might ultimately turn the eastern flank of the old work unless checked. This abrasion, however, has not increased perceptibly during the past six months.

There has also been a threatened break at what has been known as the "weak point" of the narrow beach of Smith's Island.

This point is situated about three miles below (to the south of) the old work. The breach here has always been very narrow and low, and steps have been taken within the past two years to strengthen it by means of catch-sand fences and planting of grass. Quite a volume of water at present passes in and out at this point at and near high-tide. The distance of this point from the channel of the river, (over three miles,) and the nature of the flats on the inner side, being extremely shoal and full of oyster-rocks, would seem to show that no serious break need be apprehended here. At the same time, the threatened break indicates a greater pressure of water below New Inlet, as if more passed by Zeke's Island. and through the old mouth, than before the work commenced.

At the old mouth of the river, we should expect, and hope, to find the greatest manifestation of the increased flow of water.

The gradual wearing away of Bald Head Point (on the southwest side) has continued, but not so as to increase the distance across to Fort Caswell, on the western side of the river. The beach at Fort Caswell remains unchanged.

The soundings recently taken in the Bald Head or Eastern channel indicate a constant improvement in depth, and a gradual movement toward the east, the position once occupied by the old main channel. Ten feet of water can now be carried entirely through. It is now occasionally used by vessels, and there is a prospect that it will shortly be used entirely by shipping, as the better of the two channels.

At the western or Oak Island entrance no special change has taken place. On the "bulk-head" or inner bar a depth of 9 feet has been constantly maintained.

The result of the dredging or grappling at the "logs" was one cut, 30 feet in width, entirely across the obstructions, (a trifle over a half a mile in length,) and a second cut about one-third that distance over the worst portion.

This locality proves to have been, at some day, the site of an old cypress swamp. Many stumps were removed, having a diameter of from 4 to 8 feet, together with thousands of smaller stumps, cypress knees, and roots.

These stumps were projecting above the bed of the river, were mostly perfectly sound, and showed signs of having been frequently hit by the keels of passing vessels.

PROBABLE OPERATIONS DURING THE COMING FISCAL YEAR.

In accordance with instructions received from you, I have prepared an estimate for the improvement of this river, so as to secure (by dredging) a depth of 12 feet of water at low-tide, entirely to the city of Wilmington.

With the amount of funds available, it is evident that but a portion of this whole plan of improvement can be undertaken during the coming fiscal year.

The two points which seem to most imperatively demand attention are, 1st, the bar at the mouth of the river; and, 2d, the "Horseshoe Shoal" below the New Inlet.

For operations at the mouth of the river, the suction-dredge (referred to before in this report) is already provided. The cost of running this dredge will be about $1,000 per month, or $12,000 for the entire year, if run continuously.

For cutting a channel behind the "Horseshoe," 200 feet in width at bottom, the estimated cost is, for 9 feet in depth at low water, $71,976. If reduced to 150 feet in width, the estimated cost is $53,982.

The undertaking of the latter project, together with the work on the bar, would seem, therefore, to be all that can be safely counted upon during the coming year.

With these estimates, the present amount available affords a margin of $34,000 for contingencies.

Having in view the possible necessity of repairs upon the work already completed, and the very probable necessity of steps for the strengthening of the weak points of the beach of Smith's Island, the above margin, though liberal, seems none too large under the circumstances.

Should no such contingencies arise, the balance can be profitably expended, either in giving the proposed cut behind the "Horseshoe" an increased width or depth, or in dredging above New Inlet at one or more of the points indicated in the accompanying estimate.

I am, major, very respectfully, your obedient servant,

CHAS. B. PHILLIPS,
Captain of Engineers, U. S. A.

Major W. P. CRAIGHILL,
Corps of Engineers, U. S. A.

Bids opened at 12.5 *p. m. July* 17, 1873.

Number.	Bidders' names and residences.	Quantity furnished monthly.	At what intervals and in what quantities cargoes may be expected.	Weight per cubic foot.	Location of quarries on Cape Fear River, N. C.	Time.		Price per cubic yard.	Remarks.
						Commence—	Complete—		
1	C. G. Vanderwerken, Washington, D. C.	1,000 to 2,400 yards.	Weekly, 200 to 300 yards.	2,700 to 2,800 lbs. per yd.	.....	July 25, 1873	Oct. 15, 1873	$6 22	
2	Michael Hays, Richmond, Va.	500 yards.....	Weekly, 125 yds.	.....	.....	.....	.....	8 95	
3	Wescott & Son, Portland, Me.	.....	200 to 400 tons ..	165 pounds..	.....	.....	.....	9 00	
4	Bodwell Granite Co. Rockland, Me.	1,000 yards	.....	182 pounds..	.....	.....	.....	8 50	
5	William H. French, Wilmington, N. C.	350 yards.....	Weekly.....	2 tons per yd.	Rock Hill, 7 miles above Wilmington.	Aug. 1, 1873	Nov. 1, 1873	4 00	1,000 yds. in all; will deliver on board lighters at Wilmington.
6	Strausz & Rice, Wilmington, N. C.	As required.....	As reqnired.....	.....	Seven miles from Wilmington.	.....	.....	4 00	

Bids opened at 12.5 *p. m. August* 14, 1873.

Number.	Bidders' names and residences.	Quantity furnished monthly.	At what intervals and in what quantities cargoes may be expected.	Weight per cubic foot.	Time.		Price per cubic yard.	Remarks.
					Commence—	Complete—		
1	William H. French, Wilmington, N. C.	350 yards	.....	160 pounds..	Aug. 15, 1873	Nov. 15, 1873	$4 00	1,000 cubic yards in all; delivered at Wilmington.
2	Strausz & Rice, Wilmington, N. C.....	1,000 yards.....	.....	.....	Sept. 1, 1873	Nov. 30, 1873	4 00	4,000 cubic yards in all; delivered at quarries, 7 miles from Wilmington.
3	C. G. Vanderwerken, Washington, D. C.	1,000 yards.....	Weekly.....	.....	Aug. 25, 1873	Dec. 15, 1873	5 00	3,000 cubic yards in all.

Contracts: William H. French and Strausz & Rice, at $4 per cubic yard.

Bids opened at 12. 5 *p. m. November* 20, 1873.

Number.	Bidders' names and residences.	Where lighters will be loaded.	Amount bid for, feet, board measure.	Price per 1,000 feet, board measure.	Time. Commence—	Time. Complete—
1	D. D. Barber, Wilmington, N. C.	Opposite Wilmington	223,680 111,840	$13 00 16 00	Dec. 1, 1873	Jan. 15, 1874
2	Tillery & Wilkinson, Wilmington, N. C.	Wilmington, N. C.	223,680	12 45	Dec. 1, 1873	Jan. 15, 1874
3	James H. Springer, Wilmington, N. C.*	....do	73,920	16 00	Dec. 15, 1873	Jan. 15, 1874
4	Strauss & Rice, Wilmington, N. C.	....do	223,680	13 00	Dec. 1, 1873	Dec. 31, 1873

* Will furnish 223,680 feet, board measure, if time is extended to March, 1874.

Contract: Tillery & Wilkinson, at $12.45 per M.

Statement for fiscal year ending June 30, 1874.

IMPORTS.

Month.	In American vessels.	In foreign vessels.	Aggregate.
1873.			
July	.....	$2,812	$2,812
August	.....	146	146
September	.....	9,379	9,379
October	.....	12,957	12,957
November	.....	5,339	5,339
December	$38	4,723	4,761
1874.			
January	10,864	4,533 17,766	33,163
February	10,010	1,905	11,915
March	.....	9,471	9,471
April	.....	15,280	15,280
May	.....	1,128	1,128
June	.....	22,086	22,086
Total	20,912	107,525	128,437

EXPORTS.

1873.			
July	106,473	281,170	387,643
August	16,917	199,201	216,118
September	3,800	213,326	217,126
October	11,064	272,855	283,919
November	18,913	404,372	423,285
December	19,856	449,321	469,177
1874.			
January	10,790	425,348	436,138
February	9,369	243,552	252,921
March	4,804	165,993	170,797
April	5,599	103,498	109,097
May	6,153	207,397	213,550
June	41,690	319,549	361,239
	255,428	3,285,582	3,541,010

Total exports	$3,541,010
Total imports	128,437
	3,669,447

R. W. CHADWICK.

CUSTOM-HOUSE, *Wilmington, N. C., July* 20, 1874.

Statement of the commerce and navigation for the fiscal year ending June 30, 1874.

ENTRIES.

Month.	American vessels from foreign ports.		Coastwise vessels.		Foreign vessels.		Aggregate.	
	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.
1873.								
July	.....	.....	24	11,675	3	803	27	12,478
August	.....	.....	33	16,103	9	2,543	42	18,646
September	.....	.....	28	14,710	16	4,692	44	19,402
October	.....	.....	37	17,304	21	6,347	52	23,651
November	.....	.....	18	8,893	24	6,640	42	15,533
December	3	549	17	9,841	41	11,425	61	21,815
1874.								
January	1	170	26	12,362	22	5,591	49	18,123
February	2	223	19	10,248	9	2,372	30	12,843
March	1	170	29	15,229	15	3,809	45	19,208
April	1	149	29	14,105	14	3,917	44	18,171
May	.....	.....	22	12,843	13	3,875	35	16,718
June	1	183	23	12,548	15	4,269	39	17,000
	9	1,444	299	155,861	202	56,283	510	213,588

CLEARANCES.

1873.								
July	4	1,434	14	8,854	10	2,841	28	13,129
August	4	860	17	11,018	10	2,774	31	14,652
September	1	197	19	12,976	14	4,263	34	17,436
October	4	769	19	12,693	20	5,749	43	19,211
November	7	1,423	13	7,977	25	7,036	45	16,436
December	6	1,075	15	9,729	27	7,406	48	18,210
1874.								
January	5	1,399	19	10,450	38	10,254	62	22,103
February	4	647	16	8,957	20	5,520	40	15,124
March	3	406	19	11,484	15	3,850	37	15,740
April	3	587	17	10,526	15	4,366	35	15,479
May	2	435	19	11,491	17	5,049	38	16,975
June	4	915	14	9,156	20	5,658	38	15,729
	47	10,147	201	125,311	231	64,766	479	200,224
Total entries							510	213,588
Total clearances							479	200,224
							989	413,812

R. W. CHADWICK.

CUSTOM-HOUSE, *Wilmington, N. C., July 20, 1874.*

Commerce and navigation of Wilmington, N. C., in 1872, and compared with previous years.

WILMINGTON, N. C., *October* 13, 1873.

SIR: In compliance with a resolution of the Chamber of Commerce of August 29, 1873, I have the honor to transmit herewith a report upon the commerce and navigation of the port of Wilmington, N. C., for the year ending 31st December, 1872, and compared with previous years.

I have further the honor to append hereto three tables, containing commercial statistics, carefully prepared from the most reliable sources at my command.

Attention is invited to Statement A, exhibiting the foreign exports, imports, and navigation for six years ending 31st December, 1872.

This statement, being obtained from an official source, may be relied on as correct, from which it will be seen that the exports have increased from $735,150 in 1867 to

$2,814,714 in 1872. A corresponding increase is perceptible in the imports, from $7,861 in 1867 to $300,037 in 1872. The navigation of the port shows a similar increase, as from 57 clearances of 17,339 tons in 1867 it has risen to 158 clearances of 41,528 tons in 1872.

Not the least gratifying feature in this flattering improvement in the commerce and navigation of the port is the fact that nearly the whole of it is due to the operations of the last two years.

Of the general arrivals in 1872, as appear in Statement B, fifteen were from Navassa Islands, whose aggregate of cargo amounted to 3,977 tons of Navassa phosphate, of the value of $64,000. The Navassa Islands, although foreign, are under the flag of the United States, consequently the vessels and cargoes are regarded as coastwise, and do not appear in this statement.

Attention is also invited to Statement B, exhibiting the navigation of the port, both foreign and coastwise, for the year 1872, and compared with nine months of 1873 ending 30th September, 1873, (excluding, however, vessels trading to ports within the State of North Carolina.)

This statement, being compiled from the books of the commissioners of navigation, may be regarded as official and reliable, from which it will appear that for the year 1872 there were 533 arrivals of all classes and nationalities, (of which 62 were barks and 74 brigs,) with an aggregate tonnage of 198,358; and for the nine months of 1873 there were 457 arrivals, of 169,542 tonnage, (of which 78 were barks and 68 brigs;) thus showing a monthly increase of 6 vessels and 2,308 tons thus far in this year over 1872.

I found much difficulty in procuring a correct list of the vessels arriving from ports within the State or of their cargoes, no registry of them being made by the harbor-master or any one else. Upon close investigation, however, I found seven mercantile firms who kept records of such consignments to themselves, (how many more there were I was unable to find out with any degree of accuracy, but I have reason to believe there were many.) From these I ascertained that they, in the aggregate, had received consignments during the year 1872 of 487 vessels, of about the average capacity of 200 barrels, their cargoes consisting of 256,177 bushels corn, 3,956 bushels pease and other small grain, 32,243 bushels peanuts, 57,500 pounds bacon, 20 barrels and 8 kegs lard, 3,026 barrels mullets, 58,000 barrels naval stores, 1,012 bales cotton, 782 bales of North Carolina hay.

I have further the honor to append hereto Statement C, containing a compilation of the annual report of the Daily Journal of the principal articles of produce exported from the port of Wilmington, N. C., for the year ending 31st December, 1872, and compared with those of the years 1869, 1870, and 1871.

This statement exhibits a value of exports for the year 1872 of $9,899,491; the values, not being recorded, were carefully obtained from reliable sources, and while they may not be literally correct in every instance, I think they are reliable as far as they go, and within the actual value.

It will be observed that this statement purports to exhibit only the principal articles of produce exported, and as such furnishes an approximate only, and by no means a full exhibit of the exports. In confirmation of this fact it was found, upon investigation and an examination of the freight-lists of the steamers only, (the freight-lists of sailing-vessels and railroads not being accessible or available,) that there had been shipped of articles which do not appear in this report 5,500 tons of Navassa guano, which was manufactured here, all of the productions of the Cane Fiber Company, 654 barrels of pulverized soapstone, a quantity of flaxseed, 9,440 beef-hides, 570 sides of tanned leather, a large quantity of furs, beeswax, tallow, wines, fruits, and vegetables, with various other articles, enough to justify me in the estimate of not less than $2,000,000 as the value of unrecorded exports. I therefore feel no hesitation in reporting $12,000,000 in round numbers as the actual amount of exports for the year 1872.

It will be observed from an examination of these various statements that the increase in the navigation and commerce of the port has progressed steadily, as it has rapidly done in the past three years, and it is gratifying to know that this progress is well sustained by corresponding improvements of the city and in productions of the country tributary to Wilmington, which give it the complexion of robust health, rather than the hectic flush arising from the exigencies of trade and politics.

A reason no doubt will be asked by some for this vigorous growth of the city, its commerce and navigation—where the starting point. What the impulse and the stimulant.

I know of no other or better reason than what may be found in the operations of the Government at the mouth of the river for the improvement of the harbor.

This work, commenced in the summer of 1870, has progressed steadily and successfully, but very slowly, and, thus far, may be said to be only preparatory, owing to the meager annual appropriations allowed by Congress, no amount having as yet been appropriated sufficient to justify an attempt to deepen the channel by means of dredging, which must be adopted before valuable results can reasonably be expected;

and yet the navigation has somewhat improved under this preparatory work, for it is but yesterday we hear of the British bark Nancy Bryson drawing 17 feet of water, being piloted to sea over the bar (not rip) on her voyage to London. The bare anticipation of the reality of improving the harbor has had an electrifying effect that nothing else could produce. It has stimulated commerce, trade, and city improvements; it gives value to real estate; it has infused new life and energy into our railroads, which are being rapidly pushed through the mountains with numerous tributary branches, while the subjects of opening canals, clearing out rivers and creeks, opening and improving roads and highways, and other improvements, are constantly being agitated in our midst; and this is but the beginning of the end.

It therefore becomes a duty of self-preservation to our citizens, and particularly to the merchants, to see to it that this work is not permitted to flag or falter until the last nail is driven home in the perfect completion of our river and harbor improvements.

Respectfully, your obedient servant,

H. NUTT.

NOTE.—*November* 1.—For the month of October, just closed, there were 61 arrivals of shipping, aggregating 25,432 tons, of which 18 were steamships, 15 barks, 13 brigs, and 18 schooners, (15 barks and 12 brigs being foreign,) and compared with the month of October, 1872, shows a gain of 19 arrivals and 7,682 tons in this month over the corresponding month of last year.

H. N.

Col. WM. L. DE ROSSET,
President of the Chamber of Commerce.

A.—FOREIGN COMMERCE.

Statement of vessels entered and cleared, showing class, nationality, and tonnage.

CLEARED.

Year.	Barks.	Brigs.	Schooners.	Sloops.	Nationality.	Number.	Tonnage.	Number for the year.	Tonnage for the year.
1867	4	14	1	.....	British	19	10,570	.....	.....
1867	.....	.....	1	.....	Dominican	1	95	.....	.....
1867	1	12	21	.....	American	37	6,684	57	17,349
1868	5	21	3	.....	British	32	7,633	.....	.....
1868	.....	3	.....	.....	German	3	668	.....	.....
1868	.....	2	.....	.....	Danish	2	359	.....	.....
1868	.....	1	.....	.....	Dutch	1	268	.....	.....
1868	2	16	12	1	American	31	11,214	69	20,142
1869	15	29	4	.....	British	48	11,544	.....	.....
1869	3	4	.....	.....	German	7	1,529	.....	.....
1869	.....	2	.....	.....	Danish	2	304	.....	.....
1869	1	.....	.....	.....	Norwegian	1	216	.....	.....
1869	3	14	13	2	American	32	6,478	90	20,071
1870	6	30	4	.....	British	40	8,683	.....	.....
1870	1	1	.....	.....	German	2	536	.....	.....
1870	1	2	.....	.....	Norwegian	3	562	.....	.....
1870	.....	2	1	.....	Danish	3	456	.....	.....
1870	1	.....	.....	.....	Swedish	1	297	.....	.....
1870	1	20	36	.....	American	57	11,133	106	21,667
1871	21	26	2	.....	British	49	13,700	.....	.....
1871	12	6	1	.....	German	19	5,692	.....	.....
1871	1	1	.....	.....	Norwegian	2	426	.....	.....
1871	.....	1	.....	.....	Swedish	1	202	.....	.....
1871	.....	1	.....	.....	French	1	301	.....	.....
1871	.....	1	.....	.....	Argentine	1	212	.....	.....
1871	.....	1	.....	.....	Dutch	1	164	.....	.....
1871	1	.....	.....	.....	Danish	1	396	.....	.....
1871	.....	1	.....	.....	Spanish	1	175	.....	.....
1871	3	21	28	.....	American	52	10,588	128	31,856
1872	20	23	6	.....	British	49	12,916	.....	.....
1872	26	10	.....	.....	German	36	11,345	.....	.....
1872	3	12	.....	.....	Norwegian	15	3,447	.....	.....
1872	4	1	.....	.....	Swedish	5	1,563	.....	.....
1872	2	.....	.....	.....	Spanish	2	688	.....	.....
1872	1	.....	.....	.....	Russian	1	290	.....	.....
1872	4	22	24	.....	American	50	11,279	158	41,528
Total	142	303	160	3	.....	608	152,613	608	152,613

For the year 1873, 242 vessels cleared with cargoes valued at $3,453,845.

A.—*Statement of the foreign exports and imports at the port of Wilmington, N. C., from the 1st of January, 1867, to the 31st of December, 1872, embracing a period of six years, compiled from an official source.*

EXPORTS—Valuation.

Year.	Cotton.	Rosin and crude turpentine.	Tar and pitch.	Spirits turpentine.	Lumber.	Shingles.	Miscellaneous.	Annual totals.
1867	.....	$77,931	$455	$587,326	$165,908	$3,530	.....	$735,150
1868	.....	62,969	1,951	677,834	112,611	4,136	$1,172	860,673
1869	$5,323	76,621	3,624	1,161,512	83,368	4,484	.....	1,334,932
1870	1,327	85,695	13,695	483,199	178,249	11,018	.....	773,183
1871	4,061	376,689	2,643	987,321	127,957	8,620	2,292	1,509,583
1872	55,832	784,266	16,148	1,787,403	158,924	12,341	.....	2,814,914
Total	66,543	1,464,171	38,516	5,684,595	727,017	44,129	3,464	8,022,435

For 1873, $3,453,845.

IMPORTS—Valuation.

1867	$7,861	1871	$182,309
1868	48,904	1872	300,037
1869	30,321		
1870	197,488	Total	766,920

B.—*Arrivals of shipping at the port of Wilmington, N. C., from the 1st of January to the 31st of December, 1872, compiled from the books of the Commissioners of Navigation, as registered by B. G. Bates, esq., harbor-master, and which may be regarded as official. Also for the first nine months of 1873, from the 1st of January to the 30th of September, 1873.*

American:
Steamers, 181; barks, 12; brigs, 35; schooners, 206; total, 434; tonnage, 168,767.
Foreign:
Barks, 50; brigs, 39; schooners, 10; total, 99; tonnage, 29,591.
Grand totals:
Steamers, 181; barks, 62; brigs, 74; schooners, 216; total, 533; tonnage, 198,358.

From the 1st of January to the 30th of September, 1873.

American:
Steamers, 138; barks, 1; brigs, 23; schooners, 170; total, 332; tonnage, 133,647.
Foreign:
Barks, 77; brigs, 45; schooners, 3; total, 125; tonnage, 35,848.
Grand totals:
Steamers, 138; barks, 78; brigs, 68; schooners, 173; total, 457; tonnage, 169,542.
Monthly increase of arrivals this year over the last, six, and tonnage 2,308.

C.—*Exports, foreign and coastwise, from the port of Wilmington, N. C., for the year ending December 31, 1872, and compared with those of 1869, 1870, and 1871, as compiled from the annual statement made by the Daily Journal, and from other sources.*

Articles.	Coastwise.				Foreign.				Grand totals.				Value of exports for 1872.
	1869.	1870.	1871.	1872.	1869.	1870.	1871.	1872.	1869.	1870.	1871.	1872.	
Spirits turpentine...bbls.	54,085	68,966	55,275	59,410	64,097	32,889	68,647	77,969	118,182	101,855	123,922	137,379	$3,159,717
Crude turpentine ....do..	20,537	12,929	11,392	11,558	764	3,258	2,840	950	21,301	16,187	14,232	12,508	43,778
Rosin .....do..	506,892	483,548	415,202	423,394	37,657	26,127	127,940	196,666	554,473	509,673	543,109	620,160	2,170,560
Tar .....do..	57,900	54,090	19,376	32,368	1,468	6,107	5,884	4,919	59,370	60,197	25,260	37,287	111,861
Pitch .....do..	4,869	4,694	3,570	7,072	64	190	218	275	4,923	6,814	3,788	7,347	22,041
Cotton .....bales	38,449	51,617	44,919	46,717	50	20	.....	707	38,499	51,687	44,919	47,442	3,558,150
Yarn.....do..	28	72	236	48	.....	.....	.....	.....	28	72	236	48	3,600
Sheeting .....do..	489	547	946	1,218	.....	.....	.....	.....	489	547	946	1,218	150,960
Pea-nuts.....bush	118,274	124,296	54,378	103,680	110	.....	.....	.....	118,384	124,296	54,378	103,680	129,600
Lumber.....p. p. ft	18,177,420	11,515,123	13,104,429	16,553,716	3,894,223	8,378,861	6,520,150	6,710,436	22,011,643	19,893,981	19,624,879	23,264,152	465,283
Shingles.....M	2,191,315	4,804,890	7,475,444	3,323,795	971,701	2,339,334	1,951,190	1,534,439	3,163,166	7,144,224	9,426,634	4,858,234	68,140
Staves.....M	1,558,204	842,253	890,230	136,606	9,150	.....	.....	.....	1,558,404	842,253	890,230	236,606	3,415
Shooks .....bundles	.....	.....	.....	3,539	.....	.....	.....	.....	.....	.....	.....	3,539	12,386
Total	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	9,899,491

The general navigation and commerce of the port, both foreign and coastwise, for the years 1872 and 1873, was:

	No. vessels.	Tons.	Value exports.
For the year 1872	533	198,558	$11,899,491
For the year 1873	646	237,302	12,500,000
Showing an increase in one year of	113	38,744	600,509
Foreign business for 1867	57	17,349	735,150
Foreign business for 1873	242	70,000	3,453,815
Foreign increase	185	52,651	2,617,695

Foreign imports, 1867	$7,861
Foreign imports, 1872	300,037
Increase	292,176

President Bridgers in his annual report to the stockholders for the year ending 30th September, 1873, exhibits an increased business on the Wilmington, Columbia and Augusta Railroad in two years of $317,126 $\frac{48}{100}$, which is a little more than 76 per cent.; while the Wilmington and Weldon Railroad, in the same time, has increased $159,994 $\frac{37}{100}$, which is more than 27 per cent.

The tonnage of the former has increased more than 100 per cent., and the latter over 50 per cent.

Increased number of barrels spirits turpentine, 16,033, or 91¼ per cent.

Increased number of barrels rosin, 81,643, or 91⅞ per cent.

Increased number of bales of cotton, 2,250, or 31 per cent.

Increased car-loads of lumber and timber, 469, or 155$\frac{3}{10}$ per cent.

Increased general merchandise, car-loads, (32,484,230 pounds,) 203, or 85½ per cent., showing an aggregate gain of 4,215 car-loads to the local business of Wilmington in two years.

U 22.

EXAMINATION AND SURVEY OF ELK RIVER, BELOW ELKTON, MARYLAND.

UNITED STATES ENGINEER OFFICE,
Baltimore, Md., November 18, 1873.

GENERAL: An examination or survey of Elk River, Maryland, below Elkton, was directed in the appropriation bill of March 3, 1873. The survey has lately been made by Mr. William Popp, by my direction. A copy of his report is inclosed herewith, dated November 15, 1873, accompanied by a map. The following extract is also given from a previous report by Mr. Popp, dated January 18, 1873, which was made after a rapid reconnoissance of the locality in that month:

The town of Elkton is situated in Cecil County, Maryland, about one mile above the confluence of Big and Little Elk Creeks, which form Elk River. Tide-water in Big Elk Creek extends to Elkton.

Above Elkton the creek furnishes fine water-power, its fall per mile being very considerable. Little Elk Creek also furnishes good water-power at a distance of about two miles above the confluence. Manufacturing establishments of various kinds, as rolling-mills, paper-mills, &c., have been erected on the banks of both creeks, and in close proximity to Elkton.

The town of Elkton itself contains several industrial establishments within its limits, and has the appearance of being a thriving and energetic place. For further reference in regard to population, imports, and exports of the place, its history, &c., I beg leave to refer to the appendix to this report, which was drawn up by a committee appointed by the town commissioners.

The Philadelphia, Wilmington and Baltimore Railroad, which passes through Elkton, affords at present almost the only means of transportation, because Big Elk Creek, as well as Little Elk Creek, is obstructed by bars. Heavy and bulky articles suffer very much from the high rates of freight which are of necessity charged by railroads. For this reason, and to remove the only obstacle which so far has impeded the further

growth of Elkton as a manufacturing place and the development of the surrounding country, it is desired by the citizens of Elkton to obtain a cheaper communication in the shape of a navigable channel connecting Elkton with the Chesapeake Bay.

* * * * * * *

APPENDIX.

Town of Elkton, situated at the head of navigation of Elk River, was called Head of Elk during Revolutionary War; just below the town, about one mile from the bridge, the river receives on the northwest side the Little Elk Creek, upon which Elk Landing is situated, about two hundred yards from its mouth.

In the revolutionary period, and for some time afterward, the navigation some distance above where the bridge now stands, on the main branch, was good and safe, so that vessels drawing some 8 or 9 feet water came up and discharged their lading at an old warehouse, which was burned some forty years ago.

The obstruction to the navigation was mainly caused by the sinking of two barges loaded with granite, leaving a large accumulation of sand and gravel, thus forming a bar. Later, about the period of the war of 1812, the navigation to Elk Landing was principally depended upon; a turnpike for transportation ten miles to the water of the Delaware at Christiana, Del., having been constructed by a company incorporated for that purpose.

Over this route a large trade was carried on, and large amounts of property, consisting of flour, whisky, grain, lumber, and goods of all descriptions, were carried in wagons, to be forwarded to and from the cities and States south; also from the Susquehanna country

The improvement desired is to open the navigation between the bridge and Frenchtown, so that the advantages of cheap transportation, such as water-carriage affords, may be secured in vessels drawing from 7 to 9 feet of water to the bridge and Elk Landing.

An appropriation from the Government for this object would greatly benefit the town of Elkton as well as the surrounding country, extending over into the State of Delaware. The town itself has a population of some 2,000 inhabitants, there being a number of stores, where, including lumber and manufactured articles, some $500,000 worth of goods are probably sold annually. In the town is a large flour and saw mill, using water-power, also a large match-stick factory, using steam; also an iron-foundery.

On Big Elk, the principal tributary of Elk River, there are a number of mills and factories, near the town, as follows: Brickett's flour-mills, West Amwell Iron-Works, Beldwin's two cotton-factories, Brewster's woolen-mill, Park & Smith's iron-works, not in operation; Scott's grist and saw mills; Simmons's woolen-mills.

On Little Elk, also near the town, Stile's flouring-mills, Mackell's grist and saw mills, Public Ledger's paper-mills; at Marley, Peterman & Harlan's paper-mills, Coster's paper-mills, Providence and Rook paper-mills.

All these manufacturing interests, also a large agricultural district, including also the iron-ore deposits some three or four miles east of Elkton, at Iron and Chestnut Hills, and other neighboring localities, would be largely benefited by the proposed improvement. Two railroads are also projected—one leading from Elkton to Massy's Cross-Roads, in Kent County; the other leading from Elkton to Oxford, in Chester County, Pa., where it connects with a road leading into the coal and lime regions of Pennsylvania.

Vessels can already carry about 6½ feet at low-water up to Cedar Point, the confluence of Big and Little Elk. The width of the stream varies from 100 to 150 feet. The improvement proposed is to make, by dredging, a channel of 6 feet in depth at mean low-water, which would give a depth of over 8 feet at high-water. Cheap dikes are required for regulating the banks, and to provide a place behind which to place material dredged from the river.

A channel from Cedar Point to Elkton 6 feet in depth at low-water, and 75 feet in width would cost $29,100; a channel to Elkton 6 feet in depth and 50 feet in width would cost $19,600. To obtain the same depth in the Little Elk, as high as Bennett's wharf, would cost for a channel 75 feet wide $6,700, and for a channel 50 feet wide $5,000. To make in both branches a channel 75 feet wide would therefore cost, in round numbers, $36,000; to make in both branches a channel 50 feet wide would cost $25,000.

Should it be decided by Congress to appropriate for this work, it is a

case where true economy requires the whole amount of $36,000 to be available in one sum for continuous and prompt expenditure.

It would not be expedient to commence the improvement unless at least $20,000 were available.

Very respectfully, your obedient servant,

WM. P. CRAIGHILL,
Major of Engineers.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

Report of Mr. William Popp, Assistant Engineer.

BALTIMORE, MD., *November* 15, 1873.

MAJOR: I have the honor to submit the following report on the survey of Elk River below Elkton, Md., made by me under your direction, from October 13 to 19:

An examination of the river having been made, and a report submitted January 18, which contained a general description of Elkton and the river, I beg leave, in order to avoid repetitions, to refer to that report.

The results of the late survey, which was conducted with great care, are given on the accompanying sketch. The soundings appearing on the sheet make up about one-sixth part of those taken. They were reduced to mean low-water, as determined by tidal observations taken at Howard's wharf during six days. As there were several unusually low tides occurring during the progress of the survey, it is believed that mean low-water thus determined is probably taken somewhat too low.

Elk River is formed by two branches, Big Elk and Little Elk Creeks, whose confluence is at Cedar Point. No difficulty is experienced by vessels trading on the river until they reach Cedar Point, the ruling depth up to that point being about 6½ feet at low-water. From Cedar Point up, Big Elk Creek gradually shoals, the shoalest place of it being situated about one-fourth mile below the bridge, where the available depth of water is only 1½ feet. The width of Big Elk varies from 100 to 150 feet. The bottom consists of sand and mud. The proportion of mud decreases in going up the creek, and it disappears near Ben's Gut entirely, and is finally replaced by fine gravel. Above the bridge the creek gradually assumes the character of a mountain-stream; the bottom changes from sand to gravel; numerous shoals, with only a few inches of water on them, alternate with deep holes; the banks become steep; the bed of the creek deeply cut in the surrounding land. This part of the creek has not been shown on the accompanying sketch, and no further reference will be made to it.

In Little Elk a ruling depth of about 5 feet at mean low-water is found as far up as Bennett's wharf. The channel, however, is narrow.

Both Big Elk and Little Elk Creeks are bordered along the greater part of their course by marshes, drained by numerous "guts." The reference of the marshes near the banks is about that of ordinary high-water or but slightly higher. Toward the interior of the marshes there is a sufficient fall of the ground to make it several inches below high-water. Basins are thus created which, being filled during the flood-tide, discharge their contents through the "guts" during ebb. The discharge continues some time after the turn of tide in the creeks, especially after very heavy high-tides, owing to the fact that the water admitted partly over the banks during flood is compelled to return through the narrow mouths of the "guts."

The improvements desired by the citizens of Elkton is a practicable channel, with a depth of 6 feet at low-water from Cedar Point to Howard's wharf, and a turning-place near that wharf. Some also desire to have Little Elk improved in the same manner as far as Bennett's wharf.

The proposed channel and dikes shown on the accompanying sketch would cost as follows:

Channel 75 feet wide at bottom, with proper side-slopes, 6 feet deep at mean low-water, including turning-place, 51,000 cubic yards, at 35 cents	$17,850
Dikes for regulating width of creek and retaining excavated material, 4,300 linear feet, at $2	8 600
Engineering, superintendence, &c., 10 per cent	2,645
	29,095

Same channel as above, only 50 feet wide, 36,000 cubic yards, at 35 cents	$12,600
Dikes, 2,600 linear feet, at $2	5,200
Engineering, superintendence, &c	1,780
	19,580

If Little Elk be improved, the cost will be as follows:

Channel 75 feet wide, 6 feet deep at mean low-water, from near Cedar Point to Bennett's wharf, 13,200 cubic yards, at 35 cents	$4,620
Dike, 700 linear feet, at $2	1,400
Contingencies, 10 per cent	602
	6,622

Same channel as above, only 50 feet wide, 8,700 cubic yards, at 35 cents	$3,045
Dike, 700 linear feet, at $2	1,400
Contingencies, 10 per cent	444
	4,889

Below Cedar Point no improvement is required, except the removal of two piers of a wharf near Frenchtown. They consist of a wooden crib filled with stones, and their removal would cost—

220 cubic yards crib-work, at $1	$220 00

If Big Elk is improved as above proposed, an appropriation of about $2,000 every eight or ten years will be required to maintain it in good condition.

Elkton is situated in the collection-district of Baltimore, which is also the nearest port of entry. Amount of revenue collected at that place during last fiscal year, $7,298.409.69.

For information concerning commercial importance of place and other statistical data, I beg to refer to appendix of report submitted January 18, 1873.

Very respectfully, your most obedient servant,

WILLIAM POPP.

Maj. W. P. CRAIGHILL,
Corps of Engineers, U. S. A.

U 23.

OLD-HOUSE CHANNEL, PAMLICO SOUND, NORTH CAROLINA.

UNITED STATES ENGINEER OFFICE,
Baltimore, Md., February 24, 1874.

GENERAL: An examination or survey of Old-House Channel, Pamlico Sound, North Carolina, was directed in the appropriation bill of March 3, 1873. A great pressure of other duties prevented the examination until December, 1873, when it was made by Mr. George H. Elliott. A copy of his report is forwarded herewith, accompanied by a sketch of the locality.

The channel is described in Mr. Elliott's report, as is also Oregon Inlet, through which it is connected with the ocean. The channel, if improved, would have no value unless the permanence of Oregon Inlet was guaranteed. This inlet is constantly changing in its location, and the channel through it is also variable, both in position and depth of water, being tortuous even in its best condition. The Old-House Channel itself is obstructed at a distance of about four miles from the inlet by a shifting sand bulk-head.

After considering the circumstances of this case I am brought to the conclusion that the probability of successful improvement is so small, the expense of any scheme promising permanently good results so large, and so out of proportion to the value of the commerce likely to

be benefited thereby, that I am constrained to recommend that no money be spent by the United States in the attempt to improve the Old-House Channel.

Very respectfully, your obedient servant,

WILLIAM P. CRAIGHILL,
Major of Engineers.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

Report of Mr. G. H. Elliott, Assistant Engineer.

FORT MONROE, VIRGINIA, *February* 12, 1874.

COLONEL: I have the honor to submit report on the examination of the Old-House Channel, Pamlico Sound, North Carolina, made under your direction in December last.

This channel is situated in the northeastern extremity of Pamlico Sound, adjacent to Oregon Inlet, which is its outlet to the ocean. From the inlet it extends inward in a southwesterly direction for about four miles, to what is known as the Bulk-head, where it terminates. This bulk-head (of sand) is about half a mile wide at its narrowest point; after passing over it 6 feet water is found; this gradually increases to the main channel of the sound, where there is a depth of 15 feet. Vessels entering the inlet, and bound up or down the sound, must pass through this channel, as nearly the whole of the sound in this vicinity consists of sand-flats, of which a large portion are dry at low-water, and as there is now a depth of but 4 feet on the bulk-head at high-water, the channel is but little used by coasting-vessels. Oregon, the most northern inlet south of Cape Henry, is a breach made by the ocean through the narrow beach during a very severe storm in 1847, when the tide rose, as people living there then and now say, 10 feet above ordinary high-water, and carried away nearly everything movable. It is shifting in its character, as will be perceived by reference to the sketch accompanying this report, on which are indicated the shore-lines at the date of its surveys (United States Coast Survey) in 1849 and 1862, and of the recent examination. These show that it has moved southward since 1849 some three-eighths of a mile, and from past experience it cannot but be regarded as probable that at some future day it may close up, as have others on this coast; notably, the one at Nag's Head, which defied the attempts made for its improvement. The channel out is crooked, and the depth of water variable, averaging from 8 to 9 feet on the bar at ordinary high-tide, which is about the depth on the bar in what is known as the Swash Channel at Hatteras Inlet, although on the outer bar there is a depth of 18 feet.

The advantages to be gained by the improvement of this channel and the inlet are, avoiding the difficult and dangerous navigation of Cape Hatteras and vicinity by all coasting-vessels entering Pamlico, and in case of those bound north of Hatteras Inlet for Roanoke Island, Albemarle Sound, or any of the rivers entering into it and the northern portion of Pamlico, a saving of time and distance, as at present they have to run down to Hatteras, sixty miles run south of Oregon, and then return the same distance up the sound; whereas, were they able to pass in at Oregon and through the Old-House Channel, they would be at the extreme north of Pamlico, and in a nearly central position with regard to all points of that and Albemarle Sounds.

Notwithstanding these advantages, I do not think them, at the present time, at all commensurate with the expense of such an uncertain undertaking as this improvement would be, especially as nearly the whole of the trade of Albemarle, and a large portion of that of Pamlico Sound, is now carried on through the Albemarle and Chesapeake Canal, at freight rates which compare favorably with those in other portions of the South, and freight-boats will have to be increased to a very great extent before it will be found insufficient to accommodate them, in which event the Dismal-Swamp Canal would doubtless be enlarged and re-opened.

A long and careful study of data, only to be obtained by a very considerable amount of field-work, as also of the changes to which the inlet channel and shoals in the vicinity are subject from the action of wind and tide, will be necessary to form even an approximate estimate of the cost of an improvement of any value. As an illustration of the effect of the wind, I may state that on December 26, 1873, during my stay in the vicinity, a northeast storm prevailing, the water near the bulk-head fell in a few hours 4½ feet, and on the wind changing to northwest rose with even greater rapidity, and continued to rise until it reached a level of 5¾ feet above the low-water level of December 26. This caused a change of position in the outer line of the bulk-head of several hundred feet, but no opportunity was afforded me of measuring it accurately.

Very respectfully, your obedient servant,

GEO. H. ELLIOTT,
Assistant Engineer.

Col. WILLIAM P. CRAIGHILL,
Corps of Engineers.

U 24.

JAMES RIVER AND KANAWHA CANAL.

Report of the Board of Engineers.

ARMY BUILDING,
New York, March 18, 1874.

GENERAL: The Board of Engineers convened by Special Order 17, War Department, Adjutant-General's Office, January 27, 1874, to examine and report upon the James River and Kanawha Canal project, respectfully report that they met and organized at the office of the engineer in charge, at Richmond, Va., on the 5th of February. By invitation of the president of the James River and Kanawha Canal Company, Col. C. S. Carrington, they thence proceeded, in the steam-yacht kindly placed at the disposition of the board by General W. F. Bartlett, to examine so much of the existing canal from the basin at Richmond as far up as could be compassed in a day's excursion. The following day, after having examined the locks connecting the basin with the docks along the river, they were met by a committee of both houses of the general assembly of the State of Virginia, by whom they were introduced to and received by the senate and house of representatives in session, and were presented to his excellency the governor of the State.

The same night they took passage on the Chesapeake and Ohio Railroad, accompanied by the president and chief engineer of the James River and Kanawha Canal Company, (Col. C. S. Carrington and Mr. J. M. Harris,) and the chief engineer of the Chesapeake and Ohio Railroad, (Mr. H. D. Whitcomb,) for Charleston, West Virginia.

As the proposed route down the Great Kanawha below Charleston is to consist of a sluice-dam navigation, it was not deemed necessary to extend the present examination farther west than Charleston, especially as the season of the year was unpropitious, and the character of the project could be perfectly understood without such examination. Passing Sunday, February 9, in Charleston, the board had opportunity to obtain much valuable information concerning the proposed route and the extraordinary geological features of the great Kanawha Valley.

On Monday, the 10th, the board, accompanied by the gentlemen already named, took a special train placed at its disposal by the courtesy of the Chesapeake and Ohio Railroad Company, and proceeded eastward, examining as they went the location of proposed dams for the slack-water navigation of the Kanawha and New Rivers, and stopped for the night at White Sulphur Springs, on Howard's Creek. The western end of the tunnel being about two and three-quarters of a mile below the Springs, and two and a half miles from its junction with the Greenbrier River, and the eastern end but a few miles eastward, the Springs offered the most convenient point for an examination for the location of the tunnel, and of its shafts, as well as for obtaining a comprehensive idea of the topography of the region of the summit-level. That the ground was covered with snow was of course an obstacle to that thorough examination which the members of the board would have liked to make; nevertheless, the essential features of the location, so far as the canal and tunnel were concerned, were, it is believed, thoroughly understood.

The board visited both of the proposed tunnel termini, and, besides, examined commanding points with relation to modifications, and perhaps change of location for the tunnel. They were of course unable to penetrate the mountain region where the proposed Anthony's Creek

reservoir is located; but this is a matter where mere personal examination could have added little or nothing to the information furnished by the surveys and long-protracted observations of the competent engineers who have prepared the plans and estimates.

On the following day, February 11, the board, completing its examinations in this region, proceeded to Goshen, and stopped for the night. They had intended at this point to take stage-coaches for Lexington, and thence, taking boat on the North River branch of the James River and Kanawha Canal, to follow it and the main stem to Buchanan, and through the Blue Ridge to Lynchburg. The state of the roads was reported to be such that the board concluded to proceed by rail to Lynchburg, where they arrived Wednesday evening, the 12th. One of the members and the recorder proceeded thence down the canal the same evening. The others, all except General Weitzel, who, in consequence of pressing duties, left the board at Goshen for his station, remained at Lynchburg throughout the next day, Thursday, during which, accompanied by the president and chief engineer of the canal, and by several prominent citizens of Lynchburg, they made an excursion up the canal to the upper end of Judith Pond and return, thus occupying nearly the entire day. On the following day, Friday, the president of the board left for New York by rail, while the two remaining members, Mr. Latrobe and Colonel Craighill, passing the day in Lynchburg, took the canal-packet the ensuing night for Richmond, arriving there Sunday morning.

The board having made, as well as the season of the year would permit, examination of the route, separated, to enable members, while continuing their investigations, to attend to their individual duties.

Before the reconvention of the board, on call of the president, March 9, two of the members, Mr. Latrobe and Colonel Craighill, who had been appointed a committee to examine the estimates, devoted much of their time to this duty, in which they were assisted by Mr. Harris, Mr. Hutton, and Mr. Turpin. They also visited the Hoosac tunnel for the purpose of obtaining information bearing upon tunnel-construction, and the president visited Syracuse to obtain from the actual experience of the Erie Canal important facts concerning water-consumption and lock arrangements.

The board having re-convened in New York on the 9th, were favored with the attendance of Mr. Harris (chief engineer of the James River and Kanawha Canal) and of Mr. Hutton; and their several reports and estimates were again gone over by the full board.

The foregoing account of the proceedings of the board will show that, for so vast a subject, these examinations could be but of a very general character. In such a case the obvious mode of proceeding was first to satisfy themselves that the projects presented had been conscientiously made up by competent engineers, and that their data, their *facts*, their surveys, &c., (to the extent at least purported,) were *reliable*. The board at the outset unhesitatingly affirms this to be the case in the projects submitted. The project differs, by a world-wide difference, from a mere reconnoissance of a new route. A large part of it lies over a work actually constructed; another portion over an extension of that same work actually commenced, but as yet incomplete; another portion connecting with the last-named and extending over the summit to the Greenbrier as early as 1825–'26, the subject of very accurate surveys and estimates by the subsequently eminent engineer, the late Major McNeill, United States Topographical Engineers. With his accurate topography before them, the surveys have been repeated, and again repeated since, and projects revised, and plans made with all this accumulated

information. A great modification, indeed, of the first plans has been made: first, by the late lamented Mr. E. Lorraine, (approved by all subsequent engineers,) in the introduction of the long tunnel. But to modern engineers such tunnels are no novelty, and its existence in the present plan throws no element of uncertainty, either as to practicability or cost. So, too, with regard to water-supply. There can be no reason to call in question the results of the surveys and the protracted observations, extending through a whole year, of the late Mr. Lorraine.

With regard to a very important part of the line—the Greenbrier and New River slack-water improvement from Howard's Creek to the Great Falls of the Kanawha—the engineer in charge has officially stated that he has not had adequate means of surveying, and therefore that the plans have not been founded on such perfect knowledge of the bed of the river and of its regimen as would be desirable; nevertheless, the board bear witness that the efforts of the late Mr. Lorraine and of his successor, (at the time assistant on this work,) Mr. Harris, have been most strenuous to supply the deficient information, and that their plans for locks and dams have been most carefully and conscientiously made up, while lacking in some elements for satisfactory location or for precision of estimate.

Having convinced themselves of the reliability of the data by proper evidence, the board must necessarily make these data the basis of their own opinions; and if these diverge from those upon which the plans have been based, it must, in general, be in consequence of modification of those plans being judged necessary.

With these preliminary remarks, a brief description of the project, as presented to our consideration, will now be given.

The James River and Kanawha Canal is a project for connecting the James River at Richmond with the Ohio River at Point Pleasant, by means of a canal and slack-water navigation. The canal to be constructed will have a width of 70 feet at the water-line, with a depth of 7 feet; its locks to be 120 feet between the gates, and to have a width of chamber of 20 feet. The tonnage of the boats to be used on it will be about 280 tons. The slack-water navigation to begin at the Greenbrier River, at the end of the canal, and to continue down this, the New, and the Kanawha, to the Ohio River. The locks for this navigation are designed to be 240 feet by 40 feet, with 7 feet depth of water, and to accommodate a barge of 700 tons, or four boats for the enlarged canal.

From Paint Creek Shoals, on the Kanawha, to the Ohio River, it is proposed to improve the navigation by means of open sluice-dams.

To furnish the supply of water for this improvement, it is proposed to construct two reservoirs, the first in the valley of Anthony's Creek, a tributary of the Greenbrier River, and the second in the valley of Meadow River, a tributary of the Gauley River.

The execution of the project involves work which may be subdivided as follows:

1st. The enlargement of the existing canal from Richmond to Buchanan.

2d. The construction of the projected and definitely-located portion of the canal from Buchanan to the mouth of Fork Run.

3d. The construction of the canal up Fork Run to the summit-level 1,700 feet above tide, under the Tuckahoe and Katis Mountains, by a tunnel seven and four-fifths miles long, and thence down the valley of Howard's Creek to the Greenbrier River.

4th. The slack-water improvement of the Greenbrier, New, and Kana-

wha Rivers to Paint Creek Shoals, (with occasional short canals to avoid expensive location of dams.)

5th. The open sluice-dam improvement of the Kanawha River from Paint Creek Shoals to its junction with the Ohio River.

Concerning this project, the board is required to report upon "all questions of practicability, plan, and probable cost for a water-communication to the Ohio by the way of the James and Kanawha Rivers, together with the probable time required for its completion, and the cost of maintenance when built."

On the first point, practicability of a water-communication, a resolution, adopted unanimously, shows the sense of the board:

Resolved, That, in the opinion of this board, it is entirely practicable to connect the waters of the James and Ohio Rivers by a water-navigation 7 feet in depth.

In this connection we remark that the route from Richmond as far as Coviugton (243.77 miles) is, from the first-named place to Buchanan, 196½ miles, an established work, to be merely *enlarged*, and between Buchanan and Covington (47.27 miles) a partially-executed work. There could be no doubt of the practicability of *enlargement*, unless some unusual obstacle interposed. On the contrary, we are assured by the engineers in whose charge the existing work now is, and to whom it is thoroughly well known, that not only is enlargement practicable, but that it has been carefully estimated for.

The remaining portion of open-canal route between Covington and the Greenbrier has been, almost throughout its whole length, examined by the board, and it is their opinion that it is as practicable to make the open-canal part as in parts where the work has been already executed.

With regard to the tunnel, as presented to us, it is of about the same length as the Mont Cenis tunnel, and it has a very great advantage over this, that whereas that was wholly driven from the ends, the proposed tunnel will be driven from shafts of moderate height, and at distances seldom exceeding one mile. The rock, too, is of a material very easily excavated.

With regard to the proposed reservoirs on Anthony's Creek and Meadow River, the question of practicability depends solely upon that of building dams of the required height, about which no question has been raised. The drawing of water in large volumes and the controlling of its draught, under a head of 60 or more feet, may indeed require unusual arrangements and extraordinary precautions, all, however, perfectly practicable.

With regard to the extension of the water-line from the mouth of Howard's Creek, on the Greenbrier, to the Great Falls, while the board is unanimous as to the question of practicability of a "water-communication," they are not so as to the proposed method of locks and dams, or slack-water navigation; and the difference involves very material differences in the probable cost of the work. All concur, however, in the opinion, as expressed by formal resolution, "that it may be expedient to adopt canal-navigation for this part of the line, with occasional exceptions, where it may be desirable in consequence of peculiarly favorable reaches or the necessity of water-supply."

Concerning the further extension of the water-communication of 7 feet at low-water from the Great Falls to the mouth of the Kanawha, no question of practicability has been raised, *i. e.*, that by dams and sluices, *or else* by locks and dams, it may be accomplished.

In the question of practicability, that of water-supply at the summit is necessarily involved. Accepting as reliable the surveys and observa-

tions of Anthony's Creek and its water-shed, the question of quantity of water available from that source is accepted with them. Taking actual experience on the Jordan summit of the Erie Canal for estimating water-consumption, the demand would be somewhat greater than in the estimates presented to us; nevertheless, a large surplus still remains, while, on the other hand, the whole Greenbrier Valley, from near Howard's Creek to its sources, lies above the proposed summit-level, and a large portion of its water-shed (five times that of Anthony's Creek) may be, by reservoirs, converted into gathering-ground for the canal. The board, therefore, are unanimous in the opinion that an ample water-supply can be commanded.

On the second point submitted, viz, the plan, there are minor differences of opinion applying to all that portion east of the summit, (or, more generally speaking, to all everywhere which shall be *open* canal,) which, however, will involve very considerable differences as to cost. These differences refer to whether the proposed plans, with single locks, shall be accepted as they are, or whether the locks, remaining single, shall be enlarged; or, finally, whether double locks shall be everywhere constructed and the sides of the prisms be revetted.

So far as regards the tunnel, the board is unanimously of opinion that a tunnel of the dimensions proposed, (52 broad by 34 high,) *i. e.*, wide enough for *passing* everywhere, should *not* be attempted, and, on the suggestion of one of our members, unite on the recommendation of a single tunnel with turn-outs of dimensions which will be fully set forth in his individual report, with which, hereafter, *if found necessary*, a second tunnel may be combined. It is also suggested that the tunnel and canal construction may be facilitated by raising the level 20 feet, so as to avoid the deep cutting in the narrow valley of Howard's Creek; or improved by a radical change of location, taking a point near the railroad-crossing in the ravine of Brush Creek, or Jerry's Run, for the eastern terminus, and the same point on Howard's Creek for the western. By this it is supposed that two miles of canalling would be saved, and the location laid in a more open valley (Brush Creek) than Fork Run; or, finally, and possibly, by starting from the last-named point and tunneling a distance scarcely exceeding that originally designed by Mr. Lorraine, (nine miles and a fraction,) the valley of the Greenbrier may be reached, by which the expensive canalling in Howard's Creek ravine and the feeder would be wholly dispensed with. These modifications of *location* are not mentioned as matters of positive recommendation, but as subjects for further survey, with a view to having the best possible location.

The board here remark, too, that in so long a tunnel the question of *traction* assumes a very predominant importance. Diminution of the great cost of such works impels the fixing of the very narrowest dimensions admissible. On the other hand, resistance to traction increases so rapidly, as the dimension of the tunnel is made to approximate to the dimension of the boat, that it becomes a very important question how those dimensions should be fixed; whether the diminution of width (by which the cost of excavating and arching is much diminished) may not be compensated by an increase of depth; and finally, that the *mode* of traction be positively fixed before the tunnel-section and interior arrangements are finally determined. The long experimental difficulties encountered on the St. Quentin tunnel, three and one-fourth miles long, (Belgium,) and the Pouilly tunnel, two and one-tenth miles long, (France,) in applying horse-power and steam, show that the tunnel cannot be economically and successfully planned till the matter is entirely settled. Were the question still in the form originally presented to us,

i. e., of a single tunnel wide enough for passing, this matter of traction would play a less important part, for there would be a wide water-way, (in which, nevertheless, there is still an increase of 25 per cent. in the traction, according to Mr. Hutton's calculations,) but with a narrow tunnel the question becomes of very great importance.

Concerning the plans for lock and dam navigation on the Greenbrier, New, and Kanawha Rivers, there is difference of opinion as to the applicability of the system, while it is admitted that further surveys are necessary to the final adjustment of these plans. The engineer in charge states officially to the board, "I would not build dams on bowlders, but I have no doubt of our ability to carry the work through the New River sections successfully by the use of the ultimate resort of a canal at points where others fail." As four of the New River dams, besides several others, are, in the projects before us, founded where as yet the bed-rock has not been discovered, the above statement is conclusive that the plans need revision. As there is not complete unanimity, as before observed, concerning the success of the slack-water method of navigation in this locality, the objection to it must be left for discussion in the individual reports.

On the third point submitted to the board, viz, the probable cost, the resolution of the board—that, in the opinion of the board, the water-line by the James River and Kanawha route, with 7 feet depth, may be completed in six years at a cost of not more than $60,000,000, allowing an unusually broad margin for contingencies which cannot be accurately measured; the cost may reasonably be expected to be within $55,000,000, and possibly not exceed $50,000,000—expresses the sense of the majority of the board both as to probable cost and time of completion.

It has already been stated that the estimates submitted by the engineer have been revised and in general seemed adequate for the work proposed. Indeed, the only increase in the scale of prices has been a moderate one applied to the summit-tunnel, at the recommendation of one of our members, whose experience has made him particularly authoritative on this subject. One of the members of the board does not concur in the above-specified probable cost, his dissent being founded on non-concurrence in the portion of the plans which involves slack-water navigation, and on the necessity of doubling the locks or increasing, with their dimensions, those of the canal-prism in order to accommodate the expected traffic.

Concerning the fourth and last point submitted, viz, "the benefits to commerce to be derived from the construction of such a work," the board can only speak in general terms. Indeed, it cannot be expected of its members, most of whom are little conversant with the statistics of commerce and with those intricate details which are involved in questions merely of profit on capital invested, to speak otherwise than in general terms.

In such terms the following resolution expresses the unanimous opinion of the members:

> In the opinion of the board, this route presents extraordinary claims as the measure of relief to the population of the Western States, in furnishing them for their bulky productions cheap transportation to a market, and for fostering the commerce of the United States by developing immense mineral resources now neglected.

A glance at the map of the United States east of the Rocky Mountains shows that the northern frontier is skirted by the great lakes and the St. Lawrence River, furnishing, with the adjunct of the Erie Canal, water-transportation to the seaboard to the entire northern border.

The Mexican Gulf forms the southern boundary, and, by aid of the rivers which it receives, and especially by the Mississippi, furnishes water-transportation to the regions through which these rivers ramify. On the other hand, there is a great central region for which these routes to the seaboard and a market are too long. If we regard the Mississippi River as a great north and south or meridian line of water-transportation, bisecting the country, as distinguished from the lakes and the Gulf which skirt the northern and southern boundaries, we shall find that, while this great central axis sends out to the westward its numerous great and parallel arms to the foot of the Rocky Mountains, by which it draws to itself the freight commerce of this vast region, it directs one single central arm—the Ohio—to the eastward and toward the Atlantic seaboard, and that the natural and shortest prolongation of this arm to the Atlantic seaboard is the Kanawha, and, by implication, the "central water-line" upon which we are called to report. With these general remarks, we believe we may, in this report, dismiss the subject, referring, for statistics especially relating to it, to the numerous printed documents and to appended statements of several of the individual members.

It could hardly be expected that on all points connected with so vast a project there should be perfect unanimity. Hence, while unanimous in the foregoing, the several members deem that the full exhibition of their several views requires individual expressions of opinion, which will be appended to this.

Respectfully submitted.

J. G. BARNARD,
Colonel of Engineers and Bvt. Maj. Gen. U. S. A.
BENJ. H. LATROBE,
Civil Engineer.
Q. A. GILLMORE,
Lieut. Col. of Engineers, Bvt. Maj. Gen.
WM. P. CRAIGHILL,
Major of Engineers, Bvt. Lieut. Col.
G. WEITZEL,
Major of Engineers, Bvt. Maj. Gen. U. S. A.
THOMAS TURTLE,
First Lieut. of Engineers, Recorder.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

The following papers of individual members form appendixes to this report, and are deemed essential to a full expression of the views of the board:

1. Remarks of General Barnard supplementary to the general report of the board on the James River and Kanawha Canal project.
2. Letter to the Chief of Engineers of Mr. B. H. Latrobe.
3. Letter to the Chief of Engineers of General Q. A. Gillmore.
4. Letter to the Chief of Engineers of Col. W. P. Craighill.
5. Letter to the Chief of Engineers of General G. Weitzel.

1.—*Remarks of General J. G. Barnard supplementary to the general report of the board on the James River and Kanawha Canal project.*

In the general report it is stated that "one of the members of the board does not concur in the above-specified probable cost, his dissent

being mainly founded on non-concurrence in the portion of the plans which involves slack-water navigation, and upon the necessity of doubling the locks, or to increase, with the dimensions of the locks, those of the prism, to accommodate the expected traffic."

Concerning the increase in lock dimensions without enlargement of prism, width and depth, (as the measure is understood to be in accordance with the views of the engineers of the existing canal, and as it has been unanimously not only approved but recommended by all my colleagues on the board,) I do not care to press my non-concurrence further than its verbal expression, merely stating that not having had practical experience on canals, I could only form my opinion upon the well-developed experience of the great work from which actually proposed dimensions of the work submitted to us, and of most other like canal projects, have been taken—the Erie Canal.

So far as I have had opportunity of learning that experience, the tonnage estimated for the proposed canal (three times as great as the Erie has yet ever carried) demands either double locks *or* much enlarged tonnage in its boats, to be obtained only by increasing the lock dimensions, and *with* them the prism dimensions.

For another reason I have found myself unable to acquiesce in the conclusions of the majority with regard to the plans and probable cost of the work. I refer to the proposed "lock and dam" navigation of the Greenbrier and New Rivers, on a scale such as to admit steamers or tow-boats *with* canal-barges, (locks 240 feet long and 40 to 50 feet wide.)

In order to be brief, I will allude first to that portion of the work which is least suited to that kind of navigation, viz, that portion of the New River from Bowyers's Ferry to the mouth of the Gauley. It is eighteen miles in length, and has an average fall of 15 feet per mile. The expressive term "cañon," though sometimes extended much further, is more especially confined to this portion. "The river here breaks through Sewall Mountain, and is confined throughout within narrow limits, bounded by rugged banks and precipitous cliffs rising many hundred feet above the surface of the water." Along this chasm the project shows 15 dams, averaging one and one-fifth miles apart, and 20 locks; the longest dam is 607 feet, and the shortest 317 feet. The *average* length is 404 feet; average height, (from foundations,) 30 feet. The least lift of any lock is 9 feet; the greatest 24 feet; lifts of 15, 16, 17, and 18 feet very frequent. The extreme flood-discharge of the river is estimated to be 98,000 cubic feet per second, and to flow over a dam of *average* length, (404 feet,) with a height of 17½ feet, (about.) The locks are to be 40 feet wide; to be correspondingly increased, (*i. e.*, to 46 or 48 feet,) if the enlarged lock recommended by the majority of the board be introduced into the canal part of the line.

The regimen of the river is scarcely at all known, and even the amount of flood-discharge is calculated upon the "concurrent reports of nearly all the engineers who have surveyed the river, that it seldom, if ever, rises more than 8 feet on the ledge, 1,300 feet long, over which flow the Great Falls of New River; otherwise known as Richmond Falls." The lock-gates and guard-walls are to be built high enough to exclude these floods, which are computed to rise 17½ feet on the *average* dam, and 19 or 20, probably, on those of minimum length.

The Greenbrier, to junction of New River, forty-nine miles, has an average fall of between 6 and 7 feet; and from thence to Bowyer's Ferry (about the same distance) the New River falls (average) nearly 10 feet; thence to Great Falls, eighteen miles, 15 feet per mile, as before stated. The floods of the Greenbrier are stated by Mr. Hutton to be

20 feet high; of the New River, 30 to 35 feet from Stretcher's Neck (about fifteen miles above Bowyer's) to Bowyer's, and for a few miles below Miller's Ferry 40 to 50 feet.* The Greenbrier and upper parts of New River would be, of course, more amenable to the slack-water system than the extremely unfavorable portion first alluded to; and it is quite possible that reaches of some extent may be introduced. Whenever, however, the lockage is through locks necessarily laid with full exposure to the floods, (as they must be to lock *directly from pool to pool*,) there will be the danger of destruction and the dangers and obstacles of currents. In the plans before the board there are, in all, 60 dams and 75 locks, the latter with an average lift of 14 feet.

The foregoing statement of the elements which make up the proposed "lock and dam" † navigation will suffice to show that they are very unusual. Neither Mr. Harris, (chief engineer of the James River and Kanawha Canal Company,) in his report on the subject, January 15, 1874, nor his predecessor, the late Mr. Lorraine, in answering the "objections to canals in mountain districts," cite any real precedents.‡

I would not urge my individual opinion, formed from the most thorough review of this subject of improvement of rivers which I have been able to make, against those of the numerous distinguished engineers who have planned or given their approval to the system; but as an engineer, consulted by the Government on this question, I cannot, while unconvinced of the adequacy and fitness of this link of a "great central water-line" of communication between the trans-Alleghanian States and the Atlantic seaboard, officially affirm its "practicability," though I have no doubt that, so far as mere *construction* is concerned, it is so. I believe the proper and safe basis for the project for this part of the route to be an independent canal, with perhaps the introduction of occasional reaches of slack-water which may be peculiarly favorable for navigation or necessary for the purposes of water-supply.

The rivers along which this navigation lies are very tortuous, the straight line from Howard's Creek to Great Falls having little more than half the length of their actual course. Thus far the river-channel and immediate margins have alone been made the subject of survey and study, and scarcely more than a guess can be made as to the direction and depth of the valleys of the numerous creeks that enter. It is at least within the compass of a reasonable probability that, by skillful use of these ravines as sites for the locks, combined with tunnels of greater or less length, and with occasional slack-watered portions of the river,

* *Flood-marks* of a height very much exceeding these last figures have been unmistakably discovered at one locality in the cañon. As it is exceptional in height, (69 feet,) peculiar to the locality, and never actually observed, I only allude to the recorded fact. The reduction of these floods to less than 30 feet, by the removal of bowlders, is assumed, but, to my mind, far from demonstrated. The dams, even below Bowyer's Ferry, average but 30 feet above foundations and considerably less than 30 feet above low-water. They will, therefore, be overtopped by back-water, by floods of less than 30 feet. Whether, therefore, the guard-locks and short reaches of independent canal (the sole harbors of refuge to boats caught in these floods) be submerged, depends, it would seem, on the tenability of this assumption.

† There is an important distinction to be made between a pure "lock and dam" navigation, such as this is, (with the exception of some short canal-reaches where rock foundations for dams are not found,) and a "slack-water" navigation in which favorable reaches of slack-water are introduced. The latter is not inconsistent with entire removal of lift-locks from the river to dry land

‡ Where the James River Canal passes the Blue Ridge, with a fall of about 14 feet per mile, the navigation is *independent canal*. Above and below the Blue Ridge the slack-water consists of occasional favorable reaches connected by canal, the fall being less than 5 feet per mile. So of the North River branch, where the fall is 9¼ feet per mile. The locks, moreover, are only 15 feet in width.

the canal and locks may be removed entirely from the river-bed, and the length of the line greatly reduced, doing away with most of the dams, placing the locks where their construction will (diminished to the standard size of canal-locks) cost but a fraction of the sum estimated for those of the proposed plan, and where they will be in perfect security. Against this economy must, however, be set off the increased cost of building a canal-trunk on very difficult ground, and of driving numerous tunnels.

In the initiation of a route presented as a great national measure to be undertaken by the Government for accomplishing objects which the board concurs with the warmest advocates in attributing to this, there should be no doubtful element, nor should the increased cost be any objection to the fixing of the whole project on its proper basis. The plans presented for the preparation of these rivers for lock and dam navigation by steamboats and tows are avowedly incomplete, and the estimate not presented as accurate. Their modification by the adoption *as a basis* of an independent canal, in conjunction with the adaptation of the locks and canal section to the proposed traffic, may, and probably will, increase the cost beyond the highest sum mentioned in the general report of the board. In saying this I am not to be understood as dissenting from the board as to the adequacy of the estimates on the basis on which they are made.

Respectfully submitted.

J. G. BARNARD,
Colonel of Engineers and Bvt. Maj. Gen. U. S. A.

NEW YORK, *March* 28, 1874.

NOTE CONCERNING WATER CONSUMPTION AND SUPPLY.

I. *Consumption.*—The portion of the line to be supplied from the summit-level is that stretching from Covington to the Greenbrier, and this length, *exclusive of the tunnel*, is 21.9, or, in round numbers, 22 miles.

The maximum lift of any locks (which governs the calculation) is 14 feet. For single locks Colonel Abert, in his exhaustive treatment of this question, says *two* locksful per boat should be allowed for passage of summit. For *double* locks on the Erie nearly one and a half are *actually consumed.*

As the above number of boats is (for single locks) excessive, however, I retain the computation at $1\frac{1}{2}$, and we require for lockage 10,080,000 per day=7,000 per minute.

On the Erie Canal, of almost identical section, *filtration and evaporation* consume, as tested by observation on the Jordan level, fifteen miles long, 200 cubic feet per minute. Hence, for 22 miles, 6,336,000 cubic feet per day=4,400 per minute.

Leakage at lock-gates, double locks at two extremities of the Jordan level on the Erie Canal, (one lock 7 feet on $5\frac{1}{2}$ feet lift, width 18 feet,) is 3,000 cubic feet per minute.

Our locks are single, but they have twice the lift, and they are one-ninth wider. It is rather within limits to allow the same, 4,320,000 cubic feet per day=3,000 cubic feet per minute.

There are other causes of waste, (see Colonel Abert's report,) which, on the Erie, are estimated at 900 feet per minute for this level. I will assume 500 feet; hence, for—

Waste at structures, 720,000 cubic feet per day=500 cubic feet per minute. Total, 21,456,000 cubic feet per day=14,900 cubic feet per minute.

Now it is not certain that the tunnel will consume no water,* and the feeder from the dam on Greenbrier will certainly consume a great deal. (See Colonel Abert's report.) Hence it would be better to assume as—

Total required, 25,000,000 cubic feet per day=17,360 cubic feet per minute.

II. *Water-supply.*—The total discharge of Anthony's Creek for the twelve months commencing July 1, 1851, was found by Mr. Lorraine to be 5,670 millions of cubic feet; the area of the basin one hundred and two square miles, showing an actual drainage of two-thirds the usual rain-fall of 36 inches, and more than two-thirds the rain as gauged during these twelve months, (34¼ inches.) The proposed reservoir will contain 4,806 millions of cubic feet; and as a daily evaporation of ¼ inch from its surface is allowed for 900 millions, it will practically store all the available drainage of the basin. The total annual discharge of the Greenbrier can be only inferred from the area of its drainage-basin; and this, from imperfection of maps, can be but rudely approximated to. It is probably four to five times that of its tributary, Anthony's Creek; *i. e.*, its drainage should be twenty-two and a half to twenty-eight thousand millions of cubic feet, the smallest of which numbers greatly exceeds the contents of Mr. Ellet's proposed Meadow River reservoir. How much of this drainage may be gathered and utilized for the one hundred and twenty days of summer, over and above the actual discharge of the river, (estimated by Mr. Hutton at 8⅓ millions of cubic feet per day for the summer months,) can only be determined by survey. Although McNeill says that the Greenbrier Valley is "admirably adapted to reservoirs," (he had in mind comparatively small ones,) a glance at Mr. Ellet's description and map of the Meadow River reservoir suffices to show that no such topography exists in the Greenbrier Valley, and that it would be hazardous to affirm that one-third of its drainage (by resort to numerous small reservoirs) could be collected.†

These two streams, or rather the Greenbrier alone, to which Anthony's Creek is but a tributary, are the main sources of water-supply to the summit; but it would seem that from these the supply could be readily doubled; and, indeed, much more than doubled.

Assuming that 25 millions per day (or 3,000 millions for 120 days) are required for the canal, and 2,232 millions in addition for the Greenbrier slack-water navigation, (which is but a small fraction more than is consumed in the estimated lockages,) and the total contents of the Anthony's Creek reservoir, added to the summer flow of the Greenbrier, is nearly all called for as a supply for the project now presented. A reduction of such unusual "lifts" as 14 feet in locks drawing from the summit-level would be desirable. Arrangements of locks increasing consumption cannot safely be made without increasing the supply arrangements; that is, by constructing other reservoirs, supposing, as I do, that, at the very outset, the number of lockages to be as estimated.

J. G. B.

* On the Illinois Canal deep cuts through stratified rock have been found to waste water more than other excavations, and to be difficult to puddle.

† It is possible, perhaps, though no one reservoir can be made, that by a costly succession of dams and reservoirs along the main valley, the whole drainage might be gathered.

2.—*Letter to the Chief of Engineers of Mr. Benj. H. Latrobe.*

UNITED STATES ENGINEER OFFICE, ARMY BUILDING,
New York, March 19, 1874.

GENERAL: The joint report of the board expressing the views which I entertain, in common with my colleagues, upon the points embraced in the instructions under which we are acting in reference to the proposed extension of the James River and Kanawha Canal to the Ohio River, I have only to offer some suggestions as to the mode of carrying the work into effect in its final location and construction.

In stating my opinion of its *practicability* I mean to express my belief that its *cost* will not be greater than the objects it contemplates will fully warrant. In regard to the *dimensions* of the work best suited to the accommodation of the trade to pass over it, and to the economy of its transportation, I see no reason to dissent from those upon which the plans and estimates of Colonel Craighill have been founded. I will, however, offer a suggestion on this head further on.

As respects the plans of the different structures, viz, the dams, locks, aqueducts, culverts, &c., they appear to me to be judiciously designed.

From the examination I have made of the *prices* of the different classes and kinds of work, I believe them to be sufficient, with perhaps one exception, which I will notice in its place. The proposed mode of conducting the work upon the enlargement of the existing canal between Richmond and Buchanan I think judicious—that is, to retain the present locks upon the part near Richmond, where the local trade is heavy, and place the new locks alongside of them, and for the remainder of the distance to let the new occupy the sites of the old locks, where those sites are the best, care being taken to suspend the business of the canal for as short a time as possible, which can be done by proper arrangements. The widening and deepening the canal to the new dimensions by removing deposits in it, and by excavating on the berme side, and raising and strengthening the present towing-path with the material, seems also the best manner of effecting the object, although at rocky bluffs it may be better to extend the existing embankment outward to a greater or less extent as the particular case may require.

As the improvement is partly to consist of slack-water and partly of canal, I think that the latter description of work should be preferred wherever it will not involve too great an increase of cost. From such observation as I was enabled to make upon the Greenbrier and New Rivers, it appeared that good ground for a canal could be found at a number of points and should be availed of. The dams upon these rivers, as projected, are of necessity high, in consequence of the rapid fall of the stream, and, however well-built, are not altogether free from danger. They should, therefore, be reduced to the smallest number consistent with other proper considerations, and be placed at no points where *solid rock* cannot be reached Where that foundation cannot be had, I would advise a canal, at whatever cost it would be attended by, and I will here suggest whether, in view of the very serious difficulties of construction upon parts of those rivers, and especially in the *cañon* part of New River, approaching the Gauley River, it would not be best to carry the canal and slack-water improvement of the dimensions proposed for the part of it east of the mouth of Howard's Creek, down those rivers to a point a little below the Falls of Kanawha, and make the transfer from barges to canal-boats at that point. The *cost* of this transfer will be the same at whatever point it may take place, while the locality will be more favorable at the lower

point. I am, of course, aware of the reason for extending the barge and steam-towing system as far east as may be judiciously done. At the estimates of comparative cost of freightage, which are used in the report of Colonel Craighill, it would seem that the three mills per ton per mile of *barge*-transportation, and 3.6 mills for canal-carriage, would make for the one hundred and fifteen miles from the mouth of Howard's Creek to a point a mile or two below the Falls of Kanawha a difference of 7 cents per ton. Such a difference should not, of course, be disregarded, but the question remains open whether the difference in the cost of construction and *maintaining* the two descriptions of improvement would not more than counterbalance this apparent difference in the cost of carriage. It is certainly necessary to keep the *cost of construction* always in view, otherwise, in order to cheapen transportation to the public who use the improvement, an amount of capital might be invested in it too large even for the resources of the National Government to meet.

If a canal and slack-water, with locks of half the dimensions of those required for the barge and tug system, can not only be *built* at a largely decreased cost, but *maintained* too, the tolls, which are an important part of the expense of carriage, may be reduced, even if they are intended to be no higher than will just keep the work in repair. Nor can the fact that the Government, upon which the construction of the line will devolve, may not look for interest upon its cost, render that point one of indifference, as the more dead capital it has on hand the more the people must be taxed in one form or other for its support.

This consideration may possibly be regarded as remote and indirect, especially as the part of the country most urgent for new channels of cheap transportation would, perhaps, bear but a small proportion of such increased taxation.

As I believe it has been expected by the board that I would give some special attention to the *summit-tunnel* as one of the most marked characteristics of the project, I will now submit what occurs to me to say upon that subject.

Having some years since, in a letter to the late Mr. Lorraine, expressed my entire confidence in the practicability of this apparently formidable feature of the work, I have nothing to recall in that regard. What I saw of it upon the ground recently made it assume, indeed, a more favorable aspect than before. There are, however, questions open in regard to its *location* which have already claimed the attention of the board, and which can only be decided by additional instrumental surveys. The suggestion of General Barnard as to a change in the location of the canal east of the summit, so as to make it approach the east end of the tunnel by the valley of Brush Creek or Jerry's Run instead of the valley of Fork Run, is fully worthy of careful examination, which may result in showing a tunnel of little if any greater length, with a reduction of length and cost in the canal eastward thereof. This would suppose the west end of the tunnel to remain unaltered in position, and to debouch upon Howard's Creek, as proposed heretofore. I would suggest, however, that the summit-level of the canal be raised 20 feet, or by two 10-foot lift-locks, at the west end, and 18 feet by two 9-foot lift-locks at the east end, which would allow a slope in the whole length of the tunnel (of 7.8 miles) of two feet, or at the rate of three inches per mile, to facilitate the delivery of the water eastward from the feeder which must enter at the west end of the level, and to create a slight current of about one mile per hour to assist the loaded boats in their

passage eastward. If this slope is considered too much, it may be reduced to what may be thought better to suit the purpose in view.

The walls and gates of the first lock at the east end would, of course, require to be of 2 feet additional height, to prevent waste at the first lock when boats were not passing; and, as the canal must be fed mainly from the summit as far as Covington, the surplus water which would flow to the east end of the tunnel, if a slope were given, would be passed by the flumes down to that point, to maintain the supply required by filtration and evaporation on the east side of the mountain, where this last source of waste will be somewhat greater than on the west side, owing to the more southern exposure. My chief reason for suggesting the raising of the summit-level is obviously to cheapen the cost of construction and hasten the time of completion, especially at the west approach, in the bed of Howard's Creek, where I apprehend serious difficulty would be met in the excavations, owing to the depth to which the bottom must be reduced, and at a point where the extreme narrowness and precipitous character of the ravine would make it almost impossible to exclude from the cutting the creek when swollen at all.

I have drawn upon the profile what I would propose in this case, and which, from such calculations of quantities as I have been able to make, I estimate will effect a saving of about $759,000 in the approach-cuts at both ends, the length of the tunnel remaining the same as before. Another effect of raising the summit-level the proposed 20 feet will be felt in reducing to that extent the depth of the shafts, and in cheapening their construction, and the hoisting of the material of the tunnel through them, by about $74,000, the aggregate saving equaling $833,000. From this must be deducted the cost of constructing, maintaining, and attending four locks, estimated at equivalent to $147,000; leaving a balance of about $686,000.

This additional lockage will, indeed, practically lengthen the canal about one and two thirds miles, if we assume a speed of two and a half miles per hour and 10 minutes to pass a lock. The precise value of this virtual elongation I do not propose to estimate. It may be more than enough to overbalance the advantages of the saving of capital; but we should go into these considerations in every case where a shortening of distance is invited if we do it in this. I do not myself perceive why the precise elevation of 1,700 feet above tide should be chosen more than any other of about the same height, while I fully approve the great reduction which the late Mr. Lorraine's good judgment proposed, and which meets, I believe, the approval of the entire board.

The location, plans, and estimates before us are entitled to the utmost consideration and confidence, yet, as the gentlemen who have presented them freely admit, may be susceptible of advantageous modification in their details when the work comes to be laid out and executed.

Another advantage of raising the summit-level would be felt in the conclusive reason it would afford for adopting the cut-off line at the bend first above the mouth of Howard's Creek, where the cutting would be much reduced, and about a third of a mile of distance saved over the line around the bend, reducing the loss of equated distance from increased lockage to about one mile. The creek can also on the higher level be passed under the canal by an aqueduct above the bend, and the locking-down into the basin at the Greenbrier River be made after passing through the cut.

In this connection, I would suggest whether it would not be better to move the feeder-dam upon the Greenbrier from where it appears to be placed upon the map down to the point which I have marked A thereon,

and where there would appear to be probably a good ledge foundation, judging from the bluff at that point. The dam, if placed here, would of course, be much higher and more costly than if located at the upper site, as it would feed a 20-foot higher summit-level, and the bed of the river is probably 5 or 6 feet lower, so as to make the dam some 35 feet high. The pool which would be formed as a storage-reservoir would probably more than compensate the increased cost. About a mile in length of the feeder would be saved upon bad ground. A tunnel of about 900 feet long, and a section of 15 by 10 through the point of hill at the mouth of Howard's Creek, would save a third of a mile more of difficult ground, the entire saving of length of feeder also promoting economy of water.

It is proper I should say here that if General Barnard's suggestion of a location of the main tunnel which would make it debouch directly on the Greenbrier River should be found to be preferable, then the preceding proposal to raise the summit-level may lose its force, as Howard's Creek in that case would, at the point of crossing it, be far above the level of the tunnel, and thus entirely out of the way. The length of the main tunnel would, however, in that event be increased upward of a mile, and the shafting toward its western end be perhaps separated too widely for the earliest completion of the work.

I submit some diagrams showing three different forms which the tunnel may be made to assume, the notes upon which will make their relative cost appear, leaving their relative advantages to be discussed. If expense of construction is to have the consideration usually given to it, and the reasons for a restriction of outlay of capital, *at first* at least and until the trade fully develops itself, are to prevail, my opinion is that the single tunnel, with passing-places for boats at every fourth of a mile, would be the best to estimate for. I doubt whether the rock through which the tunnel will probably pass would stand without artificial support until it could be arched, if driven of the full width of 52 feet within the lining or 57 feet exterior to it, which width in the form of tunnel proposed would be necessary for but a short length of about 140 feet at the recesses in each quarter of a mile. If, however, the system of turn-outs or passing-places be rejected, the double tunnel shown on the plan should, except so far as resistance to *traction* is involved, have the preference over the single wide tunnel. In comparing the estimated *cost* of the several plans, I have used the *prices* of the report of Colonel Craighill; although, as I have intimated above, I think that in the case of this tunnel they should be increased, in view of what has been already learned of the cost of the Hoosac Tunnel and of the contingencies affecting that of any work of the character and extraordinary magnitude of the one now in contemplation. I think it, therefore, prudent (while admitting that Colonel Craighill had good data for his own estimate) to add about 38½ per cent. to the price per cubic yard of *excavation* and 30 per cent. to that of masonry, as estimated in the report of Mr. W. R. Hutton, of the 21st January, 1871, to Colonel Craighill, increased by the addition to it made by the latter. This estimate of $5 per cubic yard for excavation and $8 for masonry in the tunnel was increased 10 per cent. for contingencies by Mr. Hutton and 5 per cent. additional by Colonel Craighill, making $5.77½ and $9.24 per cubic yard, which I propose to make $8 and $12, respectively. The price of shaft-excavation, $20 per cubic yard, I consider quite sufficient.

Applying these advanced prices to the quantities given by the single tunnel of 34 feet in clear width and similar height, with recesses every

quarter of a mile for passing boats, and assuming the whole length of the tunnel to be lined with masonry instead of one-half its length, as previously estimated, and including the cost of a towing-path of timber, we will have, as the cost of such a tunnel, 7.8 miles in length, $16,192,487, which is $884,914 more than the previous estimate of $15,307,573, for a tunnel of a uniform width of 52 feet in the clear. The narrower tunnel can be widened hereafter without interfering with its continued use to the same width of 52 feet, (which it is designed to be at the recesses,) whenever the demands of the trade may require, or should another tunnel be constructed alongside of it, the work can be executed at much reduced cost compared with the first, using the original tunnel for removal of the material through cross-connecting galleries, and boats upon the canal.

The timber platform is preferable to a solid one for the towing-path, as it enlarges the cross-section of the canal by allowing a free flow of the water within the wood-work, and so reduces the resistance to traction, while it is of cheap construction and readily repaired. Should, however, as is highly probable, steam-power be used on the canal instead of animal, the towing-path may be omitted, with an estimated saving of $123,000.

The estimated cost of the whole work may now be summed up, taking Mr. Turpin's estimate for the two hundred and sixty-one miles from Richmond to the mouth of Fork Run, and Mr. Hutton's, thence to the Ohio River, with Colonel Craighill's addition for contingencies, substituting only the estimate just offered by myself for the summit-tunnel, in place of the previous one.

From Richmond to the mouth of Fork Run, 261 miles	$14,781,644
From mouth of Fork Run to mouth of Howard's Creek, exclusive of tunnel, 12.6 miles	2,124,662
Tunnel, including towing-path of timber, and with (7.8 miles included in the above 12.6 miles) passing-places for boats each one-fourth of a mile	16,192,487
Feeder and Anthony's Creek reservoir	497,129
From mouth of Howard's Creek to Lyken's Shoals, Greenbrier and New Rivers, 116.5 miles	14,567,895
* From Kanawha River, Lyken's Shoals, to Point Pleasant, including Meadow River reservoir, 85.1 miles	1,071,290
Total Richmond to Point Pleasant, 475.2 miles	49,235,107
To which add amount allowed by Colonel Craighill upon the estimates of Messrs. Turpin and Hutton, for contingencies	2,377,738
	51,612,845
If the summit-level be raised 20 feet, deduct	686,000
Leaving	50,926,845
And if the Richmond dock and lock is deducted on the ground that it should be built by that city	1,300,000
The aggregate cost of the work would then be	49,626,845

This estimate should, in my opinion, prove sufficient if the work be judiciously conducted, the heavier parts being first got under way and the lighter ones from time to time thereafter, so as not to make too sudden demands upon the capital and labor of the country, with due regard to which consideration the work may still be completed within six years.

I have been confirmed, since submitting the first part of the preceding remarks, in the opinion that it will be best to extend the canal and

* This estimate is for an open-dam improvement of the Kanawha River, as proposed by Mr. Lorraine. Should an ordinary lock and dam system be adopted, about one million dollars would be added to the estimate.

slack-water system proposed for the line east of the Greenbrier River, to the Kanawha below the falls, in which case the present estimate for that part of the work should be so much more than sufficient to complete it upon the smaller scale, as probably to cover the additional cost of the cut-off tunnels at Big Bend and Stretcher's Neck, with a saving of upward of ten miles of distance. The water-supply would also be made more entirely free from doubt, even should the breadth of the locks be enlarged, as suggested by a member of the board.

That double locks will ultimately be required by the demands of the trade, there can be little question, although their cost may be omitted from present estimates, and the addition of them, upon the Greenbrier and New Rivers, can be more readily made on the smaller than the larger scale.

The commercial benefits of such a work, to the country at large, have been fully treated by my associates, and indeed appear to be too obvious for argument; but it is not less clear that an equally effective improvement of the Ohio River must go hand in hand with it in order that its advantages may be fully realized.

Respectfully submitted.

BENJ. H. LATROBE.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

3.—*Letter to the Chief of Engineers of General Q. A. Gillmore.*

ENGINEER OFFICE, ARMY BUILDING,
New York, March 19, 1874.

GENERAL: I have the honor to submit below my individual opinions upon some features of the James River and Kanawha Canal project, not embraced in the general report of the board appointed to examine that subject, or not treated there with that fullness which I wish to give them.

The board has expressed its unanimous approval of the project as a whole, recognizing its commanding national importance and its entire practicability, reserving divergencies of opinion among its members upon points of detail, for separate individual reports.

The project contemplates a water-line connecting the Ohio and James Rivers, assumed to be capable of carrying 9,720,000 tons annually both ways, of which 7,560,000 tons would comprise the through and way freight going East.

I am convinced, from the examination which I have been able to give the subject, that the line will attract a much larger amount of tonnage than it can possibly carry, even if its capacity should prove to be as great as that claimed for it. I therefore respectfully invite attention to the following remarks upon its commercial importance, and the deductions drawn therefrom.

The commercial importance of this line may be considered *first*, with respect to the development and distribution of the mineral wealth of the States of Virginia and West Virginia; and, *secondly*, in respect to its fitness for supplying the growing demand for cheap transportation eastward, for the surplus products of the West.

1. *The distribution of the mineral wealth of Virginia and West Virginia.*

The manufacture of iron and salt, and the mining of iron-ore and coal,

are the principal and most important local interests capable of very large development and growth in this region. They only await the means of prompt and economical conveyance and delivery of their productions to market, in a fixed time and at a fixed price, in order to spring at once into industries of vast dimensions and influence. To secure this result a direct and unbroken line of water-transportation is conceded by all to be essential.

At the present time, one single-track railroad, the Chesapeake and Ohio, traverses this region, having its termini, one on the tide-water at Richmond, and the other on the Ohio River about forty miles below the mouth of the Kanawha, while the James River and Kanawha Canal, running westward from Richmond up the valley of James River, stops at the eastern base of the Alleghany Mountains, and is therefore entirely destitute of any commercial significance whatever.

The coal and salt, all west of the Alleghanies, find for about seven months of the year, on the shallow waters of the Kanawha and Ohio Rivers, an inadequate, uncertain, and frequently interrupted means of reaching the only available markets in the West; while, with the exception of the cannel-coal, which constitutes but a small fraction of the whole, and is the only variety possessing sufficient value to bear long railroad-freights, they are entirely excluded from the eastern markets. The vast mineral wealth of the Kanawha Valley, therefore, lies practically idle and useless.

The inadequate facilities for conveying it West, repel capital, while the Atlantic States are not only deprived of all direct participation in its use, but lose the benefits of the competitive prices which its presence among them in certain and regular supplies would create.

The assumption is not without many intelligent advocates, that local interests alone are of sufficient magnitude to render this water-line remunerative, and therefore to justify its construction; that with cheap transportation from the Lower Kanawha to tide-water once established, this dormant mineral wealth, the iron-ores of Virginia and the coal-beds and salt-springs of the Kanawha Valley, to say nothing of the vast forests of valuable timber, and the products of agriculture, would be of such intrinsic worth as to attract and fix the capital necessary for its conversion into articles of trade and commerce; and that it exists in sufficient abundance, not only to require the constant employment of all, or nearly all, of the carrying capacity of the proposed canal, but also to exert a powerful influence, proportionate to its magnitude, upon ruling prices in the great distributing-markets of the country.

In this aspect the question of constructing this line assumes a national importance, independent of its functions as a conveyor of western productions to the tide-waters of the Atlantic, for domestic and foreign consumption.

In his testimony before the "Senate Transportation Committee," October 24, 1873, concerning the local trade which the line would command, Prof. David T. Ansted, of England, a mining engineer and geologist of extensive research and experience, makes the following statement, as the result of personal knowledge and investigation:

> With regard to the quantity of minerals which would have to be carried over such lines of water-communication, I can safely say, from my knowledge of the subject in various ways, that it would be, alone, sufficient to justify the construction of the canal, at the cost at which it has been placed, ($50,000,000.)

A brief description of the locality and extent of these mineral deposits will not be out of place in this connection. For more detailed information, reference may be made to various geological reports.

THE IRON-ORES OF VIRGINIA.

Professor Ansted's opinions of these iron-fields, based upon personal examination, condensed from his testimony before the "Senate Transportation Committee," are as follows:

"I find upon the line of this proposed communication one of the most remarkable iron-fields that exists upon any part of the world as at present known. It contains every variety of the most valuable ores, and these ores are distributed in such a manner as to be more accessible than, I think, in any other district. These ores extend over a wide range of country, ranging from east to west, intersected nearly at right angles by the railroad," [and also by the line of the proposed canal.] "They include the most valuable of all the known iron-ores—magnetic oxide. They include a very large quantity of the red hematite, a very large quantity of the peculiar ore known here as the fossil-ore, which is exceedingly valuable for iron-making; a very large quantity of brown hematite, and I believe other ores, which I have not, however, seen in very great abundance. But these are quite sufficient to justify what I have said with regard to the value of the district for iron production. These iron-ores exist in a belt beginning, I believe, about the position of Charlottesville, or perhaps a little east of that on the line, and they terminate, so far as I know, a little on the western side of Staunton, certain of the groups being found on the eastern side of the Blue Ridge, and others between the Blue Ridge and the Alleghanies." [This belt is about seventy miles wide along the line of the proposed canal.] "With regard to the mining of the iron-ores, that can be done at a cost below the price of mining similar ores in any part of the world which I have ever visited." [Professor Ansted had previously stated that he "had been accustomed to visit different coal-fields and iron-fields, especially in all parts of Europe, and in some parts of Asia and America, and that he had been occupied in practicing engineering as connected with geology for the last twenty-eight years."] "The ridges of ore stand up out of the ground, they have in fact kept up the hills while the country around has been removed, and all that has to be done is to run a tunnel into the hill-side, tap the lode as it comes down, and remove it from below, and bring it down. The quantity of ore which exists in this way, which I have seen, is very large indeed, and the quantity that exists in different parts of the country, which I have not seen, I have every reason to believe is enormously large. The mining for ore in that district could be done at the very smallest possible cost. It has the greatest advantages of position."

In answer to the question, "How would the cost in this region compare with the cost of the manufacturing of iron abroad?" Professor Ansted replied that "the cost of the manufacturing of the best qualities of iron which ought to be made from ores of such very high values would not be much more than one-half, at the present prices of labor here. The actual cost of making Bessemer steel, for instance, would be considered below half the cost in any part of England at the present time."

These emphatic views of a scientist eminent in his profession, and of long and varied experience as an expert, have never been questioned. On the contrary, they have been fully concurred in, without dissent, by all intelligent investigators into the mineral resources of the region under consideration.

There is no room for doubt that the line of the proposed canal between the eastern base of the Blue Ridge and the summit of the Alleghanies passes in close proximity to vast and numerous beds of iron-ore, unsurpassed in richness and in the facilities with which it can be mined and delivered to boats.

THE COAL-FIELDS OF WEST VIRGINIA.

The coal-fields of West Virginia, occupying the region traversed by the New, the Gauley, the Kanawha, the Guyandotte, and the Big Sandy Rivers, and their numerous tributaries, for many miles on either side of the main streams, are among the most remarkable in the world; certainly, much the most remarkable in America. It is here, according to

the concurrent testimony of experts in geology, that the veins of bituminous coal, found upon the entire western slope of the Appalachian chain of mountains, exhibit their maximum aggregate thickness.

Geologists also claim that these coal-fields are superior to those of Great Britain or Pennsylvania, and are indeed the finest in the world; that the *cannel*-coal of this region is fully equal to the best English or Nova Scotia cannel, and is most valuable for making gas; that the ordinary *bituminous* coal is in every respect as good as that mined in Pennsylvania; and that the Kanawha *splint*-coal possesses every requisite excellence for smelting iron-ores without coking. Experience in the use of these several varieties of coal, for manufacturing and domestic purposes, has fully confirmed these views. The Kanawha and New River coal-seams are both thicker and more numerous than those on the Monongahela, those of the splint and the bituminous varying from 4 feet to 11 feet in thickness, and those of the cannel from 2½ to 5, or even 5½, feet in thickness.

Mr. Thomas S. Ridgway, formerly of the geological survey of Virginia, made, in 1872, a geological report to the Chesapeake and Ohio Railroad Company, which passes through the coal region side by side with the proposed water-line. After describing the seams of coal which crop out on the banks of the New and the Kanawha Rivers, and several tributaries of the latter, some of which are now being worked, the report upon the coal-beds closes as follows:

> The lower coal-measures, which I have just described in detail, are comprised in twenty-four seams, eleven of which, containing an aggregate thickness of 51 feet, are workable. The pick and shovel may disclose new beds in addition. Any attempt to estimate, by calculation, the amount of coal contained within a given number of miles of your road would be futile. Without deeming it necessary to resort to a trigonometrical survey of even a small portion of the field, it is quite obvious that there are above the water-level, between Big Sewell Mountain and Charleston, within five miles on either side of the line of your road, thousands of millions of tons. The same seams could of course be reached by pits of moderate depth between Charleston and Huntington, and the amount of coal available from West Virginia is incalculably large; sufficient, allowing for a normal ratio of increase in consumption, to supply the western market for a thousand years to come.

The impracticability of sending the coal by rail to tide-water to supply the eastern markets is here recognized.

The tract of country specially referred to by Mr. Ridgway, "between Big Sewell Mountain and Charleston," about fifty miles long and ten wide, does not comprise one-half the area of the best coal-lands. It is traversed midway throughout its entire length by the proposed water-line, by means of either canal, slack-water, or sluice navigation of the New and the Kanawha Rivers. The several workable seams of coal are horizontal, or nearly so, and are separated from each other by various kinds of rock. The coal crops out, not only upon both banks of the New and Kanawha Rivers, but also up Gauley River, Coal River, Paint Creek, Cabin Creek, Armstrong Creek, and other tributaries, thus affording extraordinary natural advantages for mining and delivery to the main line. The aggregate thickness of these parallel workable seams, that is, seams located above the level of High River, varies in different localities from 30 feet to 70 feet, and the estimate that "there are thousands of millions of tons" within a distance of five miles on either side of the proposed line between Charleston and Big Sewell Mountain is certainly no exaggeration. Indeed, assuming that all the available coal-seams convenient to the route lie within this narrow strip, which we know is not the case, and that the coal covers but one-half of this area, the other half having been swept away during the process of forming

valleys, cañons, and mountain gorges; and assuming, furthermore, that the aggregate thickness of the seams is only 27 feet, or 2 feet less than the lowest ascertained thickness, the workable beds would still contain about 7,000,000,000 tons of coal within five miles of the water-line, an amount sufficient to tax to its utmost limit the entire carrying capacity of the enlarged canal, estimated at 9,720,000 tons per year, to the exclusion of all other freight, for a period of seven hundred years.

But this estimate does not really include a fourth part of the coal known to exist above the water-level in workable seams within convenient reach of the proposed line. For it has been fully ascertained by the investigation of geologists, and by numerous openings, that the *cannel*-producing region of West Virginia, in which the seams attain their greatest aggregate thickness and the coals their best quality, actually covers an area of over one thousand three hundred square miles, in a belt about sixty miles long, lying northeast and southwest, and twenty-two miles wide at right angles to this line. It is estimated by geologists and surveyors that upon about one-fourth of this area, or three hundred and twenty-five square miles, much of the coal is wanting in the valleys and gorges, and that it has an aggregate average thickness of 50 feet over the other nine hundred and seventy-five square miles. Professor Ansted places the thickness as high as 60 to 70 feet above the water-level. But, assuming the thickness at only 45 feet, this region would furnish 43,000,000,000 tons of coal, equal to 43,000,000 tons per year for one thousand years, all above the water-line, and all easily reached by short lines of narrow-gauge roads and slack-water navigation up the numerous valleys and tributaries which pierce this section in all directions.

The foregoing estimate is not conjectural. It includes only such coals as are in convenient proximity to the proposed water-line which will traverse this region east and west along the New and Kanawha Rivers, dividing it into two nearly equal parts, and cutting the coal-seams to their very base. The total coal production of the world for the year 1872 amounted in round numbers to 227,768,000 tons. Of this amount there were produced by Great Britain 120,000,000 tons, and by the United States 44,000,000 tons.

The United States doubled her production in seven years, (from 1865 to 1872,) while Great Britain in eight years (from 1864 to 1872) did not increase her coal production quite 85 per cent.

At the same rate of increase the amount of coal that will be mined in the United States by the time the proposed water-line will be completed if begun during the present year, or, say, by the year 1880, will be 100,000,000 tons.

What portion of this vast prospective supply would be at once drawn from the Kanawha coal-fields, if a method of cheap transportation were provided for it, whether one-tenth, one-eighth, one-fifth, or more, I will not undertake to estimate. I should say, however, that one-tenth, or 10,000,000 per year, would be a low estimate.

These coals will be able to replace, to a great extent, those sent across the Atlantic from England, for while the Kanawha coals can be delivered to ocean-vessels at Richmond for $3 to $3.15 per ton, after paying for mining, delivery to barge, and one-half cent per ton per mile on the water-line, the English coals cannot cross the ocean at all without paying $3 to $4 per ton for ocean-transportation alone.

With regard to the quantity of coal that can be mined annually and delivered to boats on the water-line, all testimony concurs in representing it to be very large, on account of the peculiar topography of the

country—a continued succession of ridges and valleys—which affords a multitude of outcrops.

There is, of course, an economic limit to this industry, as to all others, but in my judgment that limit could not be reached by the entire carrying capacity of the proposed line for a thousand years, even if devoted exclusively to the coal business. Professor Ansted says:

There are, I think, about twenty distinctly workable seams of coal in the middle of the district, or what I regard as the middle of the whole series of coal-bearing beds. These middle beds are workable, all of them, above the water-line. They lie almost horizontally, and are capable of being worked at a cheaper rate than any coals which exist on a larger scale in any part of Europe. There is no reason whatever why the coal throughout the whole of this district should not be obtained at a cheaper rate than is now being got in any of the mines in Europe, and I believe I may say in any of the mines of America. There is practically no difficulty whatever— no power required to lift anything. The quantity that could be mined is very large indeed. The mine valley of the Kanawha is a deep cut in the great deposit of the carboniferous beds, and this great cut is intersected at intervals by cross-cuts which afterward, almost without exception, become more or less parallel with the main line of the valley. In that way the coal is cut out into blocks of convenient size, accessible generally from two or three sides, and that facilitates the getting to a very unusal extent. In a rough way, I can say that the average quantity of coal which would be obtained on every acre of these coal-lands would be about fifty thousand tons. Forty thousand tons per acre would not be at all an unreasonable estimate. The quantity of coal that will be required in America within a comparatively short time must amount, of course, to millions of tons per annum. I believe at present the quantity is somewhere about twenty millions.* In England we are now mining about a hundred and twenty millions of tons per annum. There can be no doubt whatever that the general coal-fields west of the Alleghanies will have to supply all the manufacturing parts of America before long.

Professor Ansted further states that—

The railways cannot certainly carry the quantity of coal that is required, and the quantity of iron that will be required, to communicate between the East and West †

It will be absolutely necessary that there should be other means of conveyance, and of all the means of conveyance for raw materials, or minerals, such as coal and iron-ore, nothing can equal water.

The canal communication from east to west seems to be an absolute necessity for this district. I cannot suppose that the coal-field can be properly developed, or that the iron-field can be properly open and worked, without such water-communication being completed.

Professor Ansted also expressed the opinion—

That the price of the best West Virginia coals, particularly the splint-coals, if they could be sent by water to a shipping-place on the Atlantic, would beyond all doubt enable the coal-dealer to meet all foreign competitors in the coaling stations of St. Thomas, Jamaica, and other islands, and secure a permanent demand there, and that these coals would certainly be preferred in the various South American ports.

Mr. Wm. H. Edwards, president of the Kanawha and Ohio Coal Company at Coalburg, testified before the Senate Committee on Transportation that "with the opening of the proposed water-line, mining would commence on all our creeks and all along the river, and we would be equal to filling any demands that might arise on the sea-board."

The same gentleman, in reply to certain inquiries, says, under date of March 11, 1874:

Our company mined in 1873 88,000 tons of coal. If the water-line were completed, and we could send the coal away regularly and promptly, we could easily mine 150,000 tons per year, and hundreds of such companies could mine and deliver 150,000 tons of coal each, if there was a market and sufficient transportation; every lot of 500 acres could sustain one such company wherever the splint-coal is found and accessible.‡

* The census of 1870 gives the production for year ending June 30, 1870, at 32,863,690 tons. More recent coal statistics give the productions for the year 1872 at 44,156,263 tons.

† Virginia and West Virginia.

‡ Splint-coal is found everywhere in connection with other coals in West Virginia.

Dr. John P. Hale, a gentleman long resident at Charleston, on the Kanawha River, and acknowledged to be thoroughly familiar with the topography of the coal region, and the extent and character of the different varieties of coal, estimates the area of available coal-lands, after deducting one-third for loss by the erosion of the streams, at one thousand six hundred and sixty-six square miles, in the valleys of New and Kanawha Rivers and their tributaries. He gives (what he terms to be) a moderate estimate of 30,625 tons of coal per acre, after allowing one-fourth for waste in mining, based upon an average aggregate thickness of 25 feet. This is really the minimum and not the average thickness.

Dr. Hale, in reply to an inquiry as to the quantity that could be mined annually, writes as follows, under date of March 2, 1874:

> Take the distance you mention—say fifty miles along the main river—it would be possible to have an average of one coal operation for every mile in extent on both sides. This would give one hundred mines. If they worked full time, and produced an average of 12,000 bushels, or 480 tons each, per day, making for the whole number of mines 48,000 tons per day, this would give 240 barge-loads of 200 tons each, per day, equal to 10 boats per hour, or 1 boat every six minutes day and night. This is for the main river only, but by going only a moderate distance up the side streams which penetrate the coal-fields in every direction, the above quantity could readily be multiplied by six, giving one boat of 200 tons every minute day and night. Of course I am only dealing with *possibilities*, but you will readily see that the practical limit of these operations is not in the extent of accessible coal in this region, nor in the amount that can easily be mined, but will be in the capacity of the canal to transport it, and in the market for the coal. To any one familiar with the rapid and vast increase in the consumption of coal, the world over, the danger will not appear great of overstocking the markets, when we get cheap access to them through this canal. I think we have coal enough for the canal, and I hope Congress will give us canal enough for the coal.

With regard to the quantity of coal that can be mined annually from horizontal seams, and brought out through a single tunnel, it may be remarked that a company controlled by English capital has recently begun operations in Gauley Mountain, about three miles from the Hawk's Nest Station of the Chesapeake and Ohio Railroad, in the expectation of mining 300,000 tons of coal annually. They have tunneled into the side of the mountain through their lowest coal-seam, which is 11 feet thick, and will communicate from this tunnel with the upper seams through a vertical shaft, through which all the coal from the higher levels will be delivered to coal-cars in the main tunnel, and thence, by a double-track narrow-gauge road, to the Hawk's Nest Station.

With the water-line completed, and prompt and certain transportation thus secured, 100,000 tons per year would be a very moderate production for one company, and there is ample room for more than two hundred such companies to carry on mining operations, without occupying one-fourth the accessible outcrops, or going far from the main line, producing upward of 20,000,000 tons of coal annually. By going back eight or ten miles from the principal stream, this yearly production could be more than doubled, without touching any but the most easily accessible seams, or encountering any serious difficulties.

The manufacture of iron is also destined to become a business of very large dimensions along the proposed line, and large capital is now awaiting investment in this interest. It is in contemplation to establish furnaces, not only at the ores, but at the coals, these minerals being separated from each other by an interval of one hundred miles. A reciprocity of full, and therefore cheap, freights will thus be established, the ore moving to the coal, and the coal by return cargoes to the ore, while the manufactured iron, either of pig or rolled iron, will move to eastern or to western markets as may suit the interests of the manufacturers. A heavy business in way-freights may therefore be anticipated.

OTHER SOURCES OF LOCAL WEALTH.

I have thus briefly and imperfectly noticed the two principal minerals awaiting development in immediate proximity to the proposed water-line.

There are, however, besides the iron and coal, other valuable interests now lying practically dormant in the same region, and only requiring cheap means of transportation to become at once objects of great commercial importance. Among these are building-stone, lime, hydraulic cement, roofing-slate, salt, and vast virgin forests of valuable timber.

The manufacture of salt, even under existing disadvantages, has already become an important industry in the Kanawha Valley. At the salines above Charleston, and in Mason County on the Lower Kanawha, where the salt-brine is obtained from artesian wells, the annual production has at times reached as high as 7,500,000 bushels. It is doubtless capable of large increase. This salt is considered to be fully equal to that from Turk's Island.

Granite of excellent quality, and unsurpassed in strength, texture, and beauty by any which the New England States afford, is found in vast ledges on the banks of the James River near Richmond. With water-transportation, this granite would find a ready and desirable market in the West, in the section of country bordering the Ohio, Mississippi, and Missouri Rivers, which is destitute of building-stone of this quality and description.

The forests in the valleys of the Greenbrier, New, and Kanawha Rivers and their tributaries are very heavily timbered with black walnut, white oak, poplar, (the northern white-wood, not bass-wood,) beech, sycamore, and sugar-maple.

It will be seen from the foregoing remarks that the proposed water-line may be expected to derive a large portion of its business from the States of Virginia and West Virginia.

This local business being upon the spot will of course take precedence of through freights, and hence its consideration must necessarily enter prominently into all questions concerning the dimensions and capacity of a water-line that is intended to provide, and should provide for many years to come, without enlargement, an adequate outlet for those surplus productions of the West which, in consequence of their great comparative bulk, are unable to sustain long portage by rail.

It is in this connection only that the foregoing discussion is considered at all pertinent.

2.—*The fitness of this water-line as an outlet for western produce.*

It will appear by reference to a good map of the United States, and to table of distances and charges upon the various existing and projected through freight-lines running east and west, that the section of country which would naturally select this Virginia water-line to the eastern markets in preference to all others, because the cheapest of all, comprises the region tributary to the Ohio, the Mississippi, and the Missouri Rivers, from Wheeling to Cairo, from Cairo to St. Paul, and on the Missouri from its mouth to its headwaters, comprising the largest portion of the aggregate area of the several States bordering those streams on either side.

The ten States in the region referred to, viz, Kentucky, Ohio, Indiana, Illinois, Iowa, Missouri, Wisconsin, Minnesota, Kansas, and Nebraska, contained in 1870 more than one-third of the entire population of the United States.

According to the last census report their aggregate crop, in round

numbers, for the year ending June 30, 1870, amounted, in cereals and other productions of the soil, to 32,400,000 tons.

	Tons.
For the year 1871 these productions had increased to over..	38,381,000
Neat cattle, swine, and sheep, (1871)*	3,500,000
Total for 1871	41,881,000

Manufactures are entirely excluded from this statement. What portion of this total tonnage is an actual surplus, that can be spared for market, it is impossible to determine with great precision. The usual estimates of statisticians fix it at three-fifths in a rich agricultural district, but assuming it to be only one-half, and omitting the hay, and we have for export from these ten States, excluding manufacture altogether, a total for 1871 of 15,300,000 tons. If we suppose that the rate of increase since 1871 has been the same as that for the year previous, the surplus agricultural productions of these ten States for the year 1874, suitable for long portage by water, will exceed 20,000,000 tons. In 1870 the wheat-crop alone in these ten States amounted to 155,469,000 bushels; and the corn-crop for the same year to 475,000,000 bushels. Allowing three-fifths of the former and two-fifths of the latter as a surplus for export, at a benefit to the producer of only 28 cents per bushel on wheat and 10 cents per bushel on corn, and the same to the consumer, and the aggregate benefit to the country at large arising from a ready market for these two crops alone for a single year amounts to more than $90,200,000. The normal rate of yearly increase in the production of these two cereals would lead to much greater results at the present time.

It would not seem immoderate to estimate the annual tonnage that will seek this line within a very few years after its completion at from six to eight millions from the two Virginias, and an equal amount from the West, or say 12,000,000 to 16,000,000 tons from both sources.

3. The projected central water-line is described in the general report.

The canal is 70 feet wide at the water-level and 7 feet deep, with interior slopes of 1 upon 2, giving a bottom width 42 feet. The locks are to be 120 feet long between gates, and 20 feet wide, with 7 feet depth of water on the miter-sill.

The actual capacity of a canal of these dimensions is estimated in Mr. W. R. Hutton's report to Major Craighill as follows:

> On the Erie Canal 198 boats have actually passed through a single lock in one day; and we may therefore safely assume a capacity for 180 boats. The tonnage of the boats will be about 280 tons, but as the freight going West will not be more than one-fourth of that from the West, we will average them at 180 tons, which will show a trade of 9,720,000 tons per annum, or for a season of three hundred days.

From this it would follow that all the eastern-bound freight would be carried by a daily average of 90 boats of 280 tons each, or one boat in every 8 minutes, night and day, equal to 7,560,000 tons in three hundred days, allowing for suspension of work on Sundays and fifteen days' stoppage by ice.

This estimate of Mr. Hutton's appears to be very large, larger, indeed, than the average results obtained on the Erie Canal would seem to justify.

I believe that an average of one boat every 10 minutes would represent a much nearer approximation to the practical capacity of the canal,

*Address of Hon. W. J. McAlpine to the New York Chamber of Commerce, May 8, 1873, page 26.

if indeed this estimate be not considerably in excess. Upon the summit-level of the Erie Canal, which is double-locked, a daily average of 101 and a maximum of 200 boats pass the locks during the busy season. The tonnage both ways on the Erie Canal in 1872 was* 3,562,560 tons. The tonnage both ways on Erie Canal in 1871 was 3,580,922 tons. Through tonnage bound East, (annually,) 1871–'72, 2,637,212 tons.

These quantities are carried during a period of seven months each year. In 1871 the total through and way freights were carried an average distance of two hundred and nineteen miles for each ton.

It would seem, therefore, that a total carriage both ways of 7,560,000 tons would more than represent the greatest yearly capacity of the proposed line. This would require the boats to pass every 10 minutes, night and day, for a season of three hundred days, and evidently allows very little for contingent accidents and delays. It would provide for 6,048,000 tons of eastern-bound through and way freight. My own judgment would place the annual carriage of the line both ways considerably lower, but as I am convinced that a water-line of greater tonnage than the one recommended will be needed at a very early day, on the ground that otherwise it will fall very far short of satisfying the increasing demands that will be made upon it from the moment of its completion, it is my wish not to understate the possible capacity of the route as proposed.

It is admitted, therefore, that the proposed line, under proper administration, may be made to carry annually 6,048,000 tons of eastern-bound way and through freight.

In my judgment, and for reasons briefly set forth in the foregoing pages, the line will be required to convey within five years after its completion more than 8,000,000 tons of coal, iron-ore, and iron in Virginia and West Virginia alone, while the amount of western produce that will seek it annually will reach as high as 6,000,000 to 8,000,000 tons more; and it will fail to carry any portion of this western tonnage, except at the expense and to the detriment of local trade.

It will be necessary, therefore, to provide for a very large addition to the tonnage of the route, either by enlarging its dimensions, duplicating the locks, or by each of these modes in succession. So far as possible, arrangements for one or the other of these enlargements should be anticipated. As to their relative advantages and cost, opinions probably differ within wide limits even among experts in canal administration, and the question should, therefore, be the subject of mature preliminary study.

The width of the locks adopted in the project (20 feet) can be increased 3 or 4 feet at a cost not exceeding $1,000 per lock. Mr. Hutton's estimate is $700 per lock.† For the entire line, therefore, from Richmond to the beginning of the slack-water on the Greenbrier, comprising 157 locks, this cost would not exceed $150,000, or less than one-third of 1 per cent. on the entire cost of the work. This single change in the project would increase the tonnage of the line nearly one-fourth, as the boats could then carry 345 tons of cargo.

A subsequent enlargement could be readily and cheaply made by raising the sides of the locks and the canal one foot or more, and still another by lengthening the locks.

Adding one foot to the depth would raise the tonnage of the boats to 400 tons, and a further increase of 24 feet in the length of the lock-

* Address by Hon. W. S. McAlpine before New York Chamber of Commerce May 8, 1873.

† Mr. Hutton is an engineer of experience in canal construction and management.

chambers would restore the original and proper proportion between the length and breadth, and with 8 feet of water in the canal the boats would carry about 500 tons on 7 feet draught. Allowing 10 minutes for lockage, the yearly tonnage of the canal would then be 10,800,000 tons of eastern-bound freight. A tonnage capacity somewhat greater than this could be given to the canal recommended in the project by doubling its locks, or by making them long enough to take two boats at once.

4. The question of water-supply for the summit-level must necessarily be considered in connection with any proposed increase in the dimensions of the locks.

The locks supplied from this level are assumed to have a maximum lift of 10 feet, and the number of boats passing both ways 240 or 360 prisms of lift per diem, being an excess of 96 boats per day over the number taken above as the basis of yearly trade.

The project before the board contemplates supplying the summit-level, during the dry season, exclusively from a reservoir on Anthony's Creek, a tributary of the Greenbrier, having a discharge certainly less than one-fourth—probably less than one-sixth—that of the main stream. It would be entirely safe to assume the discharge of the Greenbrier at three times that of Anthony's Creek.*

The Greenbrier flows through a mountain gorge peculiarly favorable to the construction of dams for a distance of more than sixty miles, all above the level of the summit to be supplied. If necessary, therefore, the supply afforded by the Anthony's Creek reservoir may be increased twofold.

As an alternative the Greenbrier may be excluded, and an additional supply obtained, equal to one-third of that from Anthony's Creek, by appropriating the waters of Little Creek, Howard's Creek, and Tuckahoe Creek. Assuming this to be the case, and we have the following results, calculated with locks 24 feet wide, 144 feet long, and 10 feet lift, fed from the summit level:

	Cubic yards.
The Anthony's Creek reservoir will afford an available daily supply of	571,780
The three creeks above named will supply daily	190,000
Total daily supply of water from these sources	761,780
Quantity required daily for the use of 240 passing boats, with locks 24 feet by 144 feet, and 10 feet lift, including leakage, filtration, and evaporation.	550,000
Daily surplus	211,780

The adequacy of the water-supply for the summit-level will not be questioned by any engineer who gives the subject a few moments' intelligent thought.†

But as one-half the water drawn from the Greenbrier and its tributaries for the summit-level will be lost to the proposed slack-water navigation west of the summit, the question arises whether, with these enlarged locks, there will be water enough left for the service of the proposed barge-locks on the Greenbrier, above its confluence with New River, or, say, above Second Creek. Upon this point I am prepared to say that I see no controlling necessity for making the locks on either the Greenbrier or New River larger than those on the canal; and, if made of the same size, the water expended in lockage at the west end of the summit-level will amply suffice to carry boats through the Green-

* Report of Capt. Wm. G. McNeill, Topographical Engineers, March 24, 1828.

† It is assumed that the data supplied by the surveys and examinations of Captain McNeill and Mr. Lorraine are trustworthy. It is not known that they have ever been called in question.

brier, by drawing upon the surplus to supply any deficiency due to natural and incidental causes.

The large barges from the West can very well break freight and transfer their cargoes to canal-boats on the Kanawha River below the Great Falls. I would prefer barge-navigation on the New and Greenbrier Rivers, if readily attainable; but I do not consider the differences involved in this question of much importance.

Substituting canal for slack-water navigation on this portion of the line would add from 7 to 8 cents per ton to the cost of transportation.

Below the confluence of Greenbrier and New Rivers it is presumed there is no question of the adequacy of the water-supply for lock and dam navigation even for large barges, and I would prefer this method of improvement to that of open sluices for the entire distance from Kanawha Falls to the Ohio River.

But the improvement of the Kanawha should be considered in connection with that of the Ohio below Point Pleasant, a subject not before this board.

The only difficulties of construction at all serious in character will probably be encountered in founding the dams for slack-water navigation upon bowlders and coarse gravel and pebbles, where no bed-rock has been discovered.

In Mr. Hutton's judgment, formed after a careful examination of the localities, these bowlder-sites for dams can generally be avoided, and it may be safely assumed that, where such avoidance is impossible, a canal can be substituted for slack-water.

COST OF THE WORK.

5. As to the probable cost of the work from Richmond to the mouth of the Kanawha River, my views are expressed in a resolution of the board, passed with one dissenting voice, that $60,000,000 would build it, leaving a large margin for contingent expenses, while its cost would probably not exceed $55,000,000, and possibly not $50,000,000.

COST OF MAINTENANCE.

6. The annual cost of maintenance and administration should not exceed $750,000, but may possibly reach $1,000,000.

PROBABLE TIME FOR ITS COMPLETION.

7. The time required to complete the work and open it to trade will depend upon the time occupied in constructing the long tunnel. I judge that five and a half to six years will be ample.

SUMMARY.

1. The construction and maintenance along the proposed route of a water-line of even larger dimensions than the one proposed is entirely practicable, and the necessity for it is so imperative, and its importance to the country at large so great, that the General Government may well assume the work, even at a cost greatly in excess of the estimates.

2. The line as proposed, when working to its full capacity, will carry, as claimed in the project, 7,560,000 of eastern-bound through and way freight annually. I place its tonnage lower by more than 1,500,000 tons.

3. The line will be required within a short time after it is opened to convey eastward more than 12,000,000 tons annually.

Its construction, therefore, should be begun with a view to increasing its capacity at an early day, either by duplicating its canal-locks or by enlarging the single line, as shall be deemed of most advantage.

4. The cost of the work, if the locks be made 4 feet wider than the project contemplates, should not greatly exceed $50,000,000, but may reach $60,000,000, and the annual cost of its maintenance will be within $1,000,000.

By widening the proposed locks 4 feet, the tonnage of the canal would be increased nearly one-fourth.

5. The time for completing the work should not exceed five and a half to six years.

Very respectfully, your obedient servant,

Q. A. GILLMORE,
Lieut. Col. of Engineers, Bvt. Maj. Gen., U. S. A.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

4.—*Letter to the Chief of Engineers of Col. W. P. Craighill.*

UNITED STATES ENGINEER OFFICE,
New York, March 19, 1874.

GENERAL: The board of engineers which, under your instructions of January 28, 1874, convened in Richmond, Va., February 5, and has since been engaged in examining the route of the proposed James River and Kanawha "water-line," and the maps and documents relating to the subject, yesterday agreed upon a report indicating its opinions upon points as to which there was entire unanimity, with the understanding that separate papers should be prepared by each member, for the purpose of a more detailed setting forth of the special views of each as to parts or the whole of the project.

While the general opinions expressed in my printed reports of January 27, 1871, and April 11, 1873, are still entertained, further reflection and conference with my able and experienced colleagues on this board have induced me to modify to a limited extent my views as to some of the details. I feel bound (and the duty is certainly a pleasing one) to make a matter of official record my testimony to the courteous consideration manifested toward me by my associates.

Your instructions direct the board to take into consideration and report upon all questions of practicability, plan, and probable cost for a water-communication to the Ohio by the way of the James and Kanawha Rivers, together with the probable time required for its completion and the cost of maintenance when built. These instructions also contain the following paragraph: "It is also desirable to have the views of the board on the benefits to commerce to be derived from the construction of such a work."

The letter of Hon. H. G. Davis, of the Senate of the United States, to the Secretary of War, dated November 12, 1873, in which he asks for the organization of a board of engineers to consider and report on the "water-line," contains a paragraph quoted below. It may properly be mentioned here that Mr. Davis writes in his capacity of member of the

Special Committee (of the Senate) on Transportation Routes to the Seaboard. He says:

You are aware of the fact that several surveys and official reports have already been made by the State of Virginia and the General Government in regard to this work, all of which seem to indicate that the project is perfectly practicable. Some of the friends of the enterprise, however, desire to present such additional evidence in regard to the cost of the proposed tunnel and of the entire canal, the water-supply of summit-level, the probable time required to complete the tunnel and the entire canal, and other questions involving its practicability as will place all these questions beyond doubt in the public mind. * * * * * It is for these reasons I have made the foregoing request as to the appointment of a board of survey, who shall carefully examine and pass upon all the computations and deductions of the engineers who have located the canal and estimated its probable cost, the time required for its construction, and other questions of a practical nature.

The question of "*practicability*" is of little importance until the fundamental one be settled of "*the benefits to commerce to be derived from the construction of such a work.*" When the *commercial working-capacity* of the line is determined by the engineers, its *commercial value* seems rather a question for the political economist. As to the commercial value, so much has been written that I might, perhaps, with propriety pass it by entirely. I desire, however, to invite special attention to the emphatic and unanimous opinion of the board, expressed in the following resolutions:

Resolved, That, while the board is of the opinion that for ordinary passenger-travel and many kinds of freight the railroad will be properly preferred as the means of transportation, there can be no reasonable questioning of the fact that, when the circumstances of the case are such that comparative slowness of movement is permissible, and the quantities to be moved large, the cheapness of transportation by water becomes obvious to every one who fairly weighs the statistics on the subject. In this view very great benefits to commerce would be derived from the construction of a water-communication from east to west between the James and Ohio Rivers.

2. Whereas the James River and Kanawha route being among the few south of the Erie Canal route over which it appears to be practicable to establish a water-navigation connecting by the Ohio River the immense internal navigation of the great Mississippi Valley with the seaports of the Atlantic; and whereas it will probably furnish the most direct connection; and whereas the route has very great local advantages of climate, owing to which it will be comparatively little obstructed by ice, and of geological character, connecting the richest coal-fields of the world (now lying almost undeveloped for want of adequate means of removal) with the markets of the world, and at the same time with the almost equally rich region of iron and other ores in the Virginia Valley:

Therefore, in the opinion of this board, this route presents extraordinary claims as the measure of relief to the population of the Western States, in furnishing for their bulky products cheap transportation to a market, and for fostering the commerce of the United States by developing immense mineral resources now neglected.

As to the *commercial value* of the work, the light thrown by the following statistics from the history of the Erie Canal is valuable:

The entire cost of constructing the Erie Canal to 1863 was $38,977,831, (nearly $39,000,000.) This sum, with interest to 1863, amounted to $52,491,915. During the same period the gross receipts from tolls were $71,783,676, (nearly $72,000,000.) After deducting expenses, ($12,518,860,) there remained a net profit of $59,264,812, not only sufficient to pay the entire cost of construction with interest, but leaving a surplus of nearly $7,000,000. Of the gross earnings it appears that but little more than *one-sixth* was required to meet expenses and repairs. *Five-sixths* were net gain. This included not only the period after the enlargement but before, when the canal was in an unfinished condition, with cost of repairs greater and receipts less. Since 1862 the net earnings have been about $20,000,000 more. From 1862 to the end of the fiscal year 1868, the amount of tolls paid to the State was $25,260,384. No other improvement, railroad or other, can make such an exhibit. The Erie Canal has not only paid for its construction, but makes itself a present to the State with about $27,000,000 of net profits. * * * For the months of October and December of 1867, the receipts from tolls were about two millions, being a little more than half the receipts for the fiscal year and more than half the estimated receipts for the next fiscal year. These figures show that the navigation closes just when the demand for

transportation is greatest, and the comparative smallness of receipts for the other five months of open navigation shows that the freight which cannot use this canal gets to market over other and much more expensive avenues of transportation.

With reference to the Erie Canal, one who knows whereof he speaks uses the following language:

The Erie Canal now conveys one-fourth of the whole of the exports of that vast interior region which I have already described, and as much of it during its six months of uninterrupted navigation as all of the trunk-railways together during the same time. Every canal-boat which comes to this city with an average cargo is more than the average of the New York Central Railroad trains. In the busy canal-season, more than one hundred and fifty such boats come daily to tide-water, and the New York Central Railroad traffic never reaches thirty trains per day. Such a canal-traffic would make more than twenty miles of railroad-cars. The slow, plodding canal-boat attracts no attention, while the bustle, noise, and whirl of a freight-train create a sensation in every village through which it passes.

See also the remarks of Mr. Harris, the present chief engineer of the James River Canal:

First, as to the supply of tonnage. By the statistics alluded to we find that the States bordering on the water-line produced in the year 1871 more than four times as much corn and about three times as much wheat as all the remaining States of the Union, and that the quantity of wheat, corn, rye, oats, barley, buckwheat, and potatoes amounted to the enormous sum of 1,134,726,000 bushels; averaging these articles at only 50 pounds to the bushel, we have 27,887,200 tons. These same States produced also the same year 109,094 tons of tobacco and 10,385,000 tons of hay. These sums added together make a grand aggregate of 38,381,294 tons. Suppose one-third of this is deducted for home consumption, the remainder is 25,587,530 tons, to which, if we were to add the tonnage of salted pork, beef, live stock, and that created by the forests and mines, the grand total would probably be at least 30,000,000 tons.

This same report also informs us that the increase of the population west of the Mississippi during the last decade was at the rate of 52 per cent., while that of the whole country was only 22 per cent. As the productions increase at least in the same ratio as the population in this productive country, may we not reasonably conclude that by the year 1880, or by the time the water-line can possibly be completed, this country will produce forty or fifty millions of tons for export? Can there, then, be a reasonable doubt that this line will be supplied with as much tonnage as it can carry, taking into view that it will be the cheapest and safest of all the lines of transportation for the tonnage of this country? Instead of a deficiency of tonnage, I think the result will be that this line cannot carry it all, though worked to its utmost capacity, and the people of the West will very soon demand another water-line to be made from the Mississippi Valley to the Atlantic Ocean, to carry off the surplus of their inexhaustible and fertile country.

Secondly, as to some of the benefits to be derived by the Western States bordering on the Ohio and Mississippi Rivers. The average result in favor of the Virginia water-line, as compared with seventeen different lines of transport, as shown in the table heretofore referred to, is $2.84 per ton. This is equivalent to the gain of 8¼ cents a bushel on wheat, and within a fraction of 8 cents per bushel on corn, and in the same proportion for all other articles. Let us suppose that this line, when finished, will have the influence of thus cheapening the cost of transportation for twenty-five miles on each side of the rivers, extending from the mouth of the Kanawha to Dubuque, a distance of thirteen hundred and fifty-five miles. This would embrace an area of country containing 43,360,000 acres.

By the report of the statistician of the Agricultural Bureau the States bordering on the rivers between the mouth of Kanawha and Dubuque produced in 1871 11.3 bushels of wheat and 35.7 bushels of corn per acre. It was shown by the table of cost referred to that the Virginia line would save to the people of the Western States 8¼ cents per bushel on wheat and 8 cents on corn. It is clear that 8¼ cents multiplied by 11.3 bushels would give the amount realized per acre on all the wheat-land, and $2.85.6 per acre on corn-land. Let us again suppose that one-fourth of this area of country was cultivated in wheat in 1871, and one-fourth in corn; by multiplying one-fourth of the area by 90.4 cents, and another fourth by $2.85.6, these products added together show what the farmers of this region lost by not having the water-line in 1871, and what they would now gain every year on their crops of corn and wheat only by having it constructed. The result would be as follows: 10,840,000 acres multiplied by 90.4 cents, $9,799,360; 10,840,000 acres multiplied by $2.85.6, $30,959,040. These sums added together make the sum of $40,758,400 that would be realized by the agriculturists of this portion of the country per annum without any more labor on their part, and would be, in effect, enhancing the value of their real estate by the enormous sum of $679,306,666.66, because it would take this capital, put at interest at 6 per cent., to pro-

duce that amount of pecuniary benefit derived per annum by the construction of this great work. The recent successful application of steam-navigation on the Erie Canal assures us that the day of slow-plodding horse-traction on large canals, such as this will be, has passed; and that the new era of steam-navigation has begun, and will be fully inaugurated before this great line can be finished, diminishing the time by one-half and the expense one-half, or reducing the total expense of navigation on the canal to less than one-half what it is at present. At these rates the actual cost of transporting a bushel of wheat three thousand miles would be only about 7 cents, and the total charges not more than 15 cents per bushel; and the effect upon the wheat and corn growing regions of the West would be not only to make two bushels of wheat grow where only one grew before, but to cause millions of bushels to be grown where none were grown before.

In this connection I will simply advert to a suggestion made by another member of the board. The need for a cheap means of transportation between East and West becomes specially pressing upon the producers of the Wes ern and Northwestern States at the very season when the Erie route fails them, from climatic causes which may be said to be uncontrollable. The Ohio River is then in a favorable condition for navigation, even without further expenditure for its improvement, and if the James River water-line were completed there would be a through line at once for this urgent work of transportation. It has been also well suggested by the recorder of our board that the boats on the Erie Canal instead of remaining idle for five months every year, could be readily transferred, and work on the James River line during the period of closure of the Erie. This transfer could be easily effected through the Delaware and Raritan Canal and Chesapeake and Delaware Canal. This means at once places the great commercial metropolis of our country, New York, in connection with the James River line. It will be found this route also compares favorably in distance with others to New York from the West.

As to the commercial capacity of the James River line, what has been hitherto written has had reference generally to a channel of the same dimensions as the existing Erie Canal, and the estimates of cost submitted in my reports contemplated such a navigation east of the Alleghany, permitting the use of boats of about 280 tons, while those of 700 tons were expected to be brought from the West as far as the summit-level, the long tunnel. That a water-communication of the capacity of the Erie Canal can be built along the James River line is believed by the board, as appears from the following resolution, unanimously agreed to:

Resolved, That, in the opinion of this board, it is entirely practicable to connect the waters of the James and Ohio Rivers by a water-navigation of 7 feet depth.

Differences of opinion prevail in the board whether the slack-water navigation should be adopted for the Greenbrier and New Rivers, or whether the smaller canal should be continued down those streams. There are also differences of opinion as to the best dimensions and details for locks, &c. Before those details can be settled further surveys will be necessary.

The following resolution agreed to by four of the five members of the board, may be here quoted:

Resolved, That, while the estimates have hitherto been limited to a water-line with canal-locks of 120 by 20 and slack-water locks of 240 by 40, the board is of the opinion that the canal-locks should probably be built of 23 or 24 feet width, with a corresponding increase in the width of slack-water locks, with a view to increase of capacity for the line in future if demanded, as this additional width can be economically given. Additional depth could thereafter be readily obtained, to as great an extent as the water-supply would permit, by raising the walls and banks.

The dissenting member, it is understood, has not satisfied himself fully as to the proper manner of giving increased capacity to the canal, whether by enlarged single locks or by doubling them.

My own opinion on this point is that the capacity of the canal should be as great as the water-supply and economical working will justify. Inasmuch as the expenses for making a lock 24 feet wide rather than 20 feet is very small in the first construction as compared with the total cost, I recommend that they be so built. If this should be found to be too great width, they may be narrowed easily and cheaply. If the water-supply be found greater than expected, the locks and canal may readily, and at comparatively small expense, be made deeper by raising the walls and banks. The continuous slack-water navigation on the Kanawha, New, and Greenbrier should have locks at least double in length and width of those on the canal, so as to pass at once four canal-boats or three boats and a tow-boat if desired. My opinion is, further, that only single locks should be first built. If the trade justify, they should be afterward doubled. The enlargement of the prism proposed in my report of January 27, 1871, is considered ample, as it will suffice for the locks of greater width now recommended, and by revetting the slopes and making them steeper the canal may be adapted to the use of steam-navigation, which should be confidently expected in the future. As a steamboat may readily be propelled at twice the speed of the horse-boat, the time of passage through the canal and its locks will be lessened one-half, and thus the capacity of the route be practically doubled.

As pertinent to this question I will here quote some interesting statements made by Maj. W. McFarland, of the Corps of Engineers, who has given much special and intelligent study to the subject of the construction and use of canals. He is writing about another canal-route than that by the James River:

> The extreme tonnage of the boats passing through the Erie Canal is, according to the last published reports, about 240 tons, while the average load is about 220 tons. The locks here are 110 feet long and 18 feet broad; the boats commonly 95 to 97 feet long and 17 feet 6 inches broad. I desire here to call attention to a curious and important fact. The Delaware and Raritan Canal, which forms a link of the inland line of water-communication between the cities of New York and Philadelphia, is of the following dimensions: Eighty feet wide at the water-surface; average depth, 9 feet; locks, 220 feet long, and 24 feet wide. The largest horse-boats plying upon this canal can carry 450 tons, but the average actual cargo is about 210 tons.
>
> Mr. John S. Hillis, of the firm of W. P. Clyde & Co., of Philadelphia, formerly superintendent of the Raritan and Delaware Canal, stated to the New York commissioners on canals, as the result of his experience, that the most economical boat or barge for this canal is 110 feet long by 23 feet 3 inches beam, carrying 300 tons. Boats 140 feet long and carrying 500 tons have been tried, but, on account of extra expense of crew to meet the increased difficulty of management, were not found economical.
>
> The auditor of the canal department of the State of New York, in his report for the fiscal year ending September 30, 1872, says: "From the experience of the season of 1872, our canals, in their present condition, are equal to all the requirements likely to be demanded of them in 1872, and have no rival on the score of cheap transportation at the present time."
>
> We may rest satisfied, then, that the 300-ton boats, which would be able to pass through our proposed canal when completed, are the largest that can be economically handled, at least until the tonnage of this canal shall exceed that of the Erie Canal, which for the year ending with the navigating season of 1872 amounted to nearly six million and a half tons.

As to the question of *practicability*, the opinion of the whole board is fully expressed in a resolution already quoted in another connection, which will be repeated here:

> *Resolved*, That, in the opinion of this board, it is entirely practicable to connect the waters of the James and Ohio Rivers by a water navigation of 7 feet depth.

As to some of the important features of the route, the opinions of the board, as expressed in other resolutions, will be now given:

> *Resolved*, That the board is of the opinion that it is entirely practicable to drive the long tunnel through the Alleghany Mountains, by which it is proposed to connect the

headwaters of the James and Greenbrier Rivers. The cost of such a tunnel, 34 feet in clear width, with passing-places for boats each one-fourth mile, would be about $2,000,000 per mile. The time of completion need not be over six years.

In this opinion the board was unanimous.

Resolved, That the board is of opinion that by the use of reservoirs on Anthony's Creek and the Greenbrier River, a sufficient supply of water may be had for the tunnel summit-level and its dependencies, and that the supply of water is also sufficient for the portion of the proposed water-line east and west of the high level.

In this opinion the board was unanimous.

Resolved, That the board is of the opinion that it is entirely practicable to enlarge the existing James River Canal and slack-water navigation to Buchanan, making the locks 120 by 20 feet, and the width of the canal at the water-line 70 feet, with a depth of 7 feet; and to extend the canal and slack-water navigation of the same dimensions to the eastern portal of the long tunnel, thus admitting the use of boats of 280 tons burden.

In this opinion the board was unanimous.

Resolved, That, in the opinion of the board, the preparation of the Kanawha River for navigation from the Ohio to the Great Falls of the Kanawha by boats of 700 tons is entirely practicable.

In this opinion the board was unanimous.

Whereas there are differences of opinion among members of the board as to the practicability of lock and dam (or slack-water) navigation of the Greenbrier and New Rivers between Howard's Creek and the Great Falls of the Kanawha; and

Whereas the same differences of opinion prevail as to the extension of the barge-navigation of the Kanawha above the Great Falls:

Resolved, That, in the opinion of this board, it may be expedient to adopt canal-navigation for this part of the line, with occasional exceptions where it may be desirable in consequence of peculiarly favorable reaches or the necessity of water-supply.

In this opinion the board was unanimous.

One member of the board is emphatically of the opinion that the use of the canal instead of the slack-water method is not only expedient along the portions of the line mentioned in the last resolution, but that the slack-water method is inapplicable along that portion. He will, no doubt, set forth his views on this subject with the usual force and clearness of his expressions. With great deference, I feel unable to reach the same conclusions, but do not entertain a doubt as to the practicability of extending the slack-water navigation over that portion of the line, if necessary. The question of the expediency of doing so may be regarded as still open, but my opinion is decided that, while it may be desirable to resort to some tunnels on New River, with the view of shortening distance and time of passage, as well as avoiding some probably unfavorable sites for dams, as well as interference with the railroad, the slack-water navigation of that river should be adhered to, as well as of the Greenbrier. By making the change from 700-ton boats to ordinary canal-boats take place, as suggested by one or more members, near the Great Falls of the Kanawha rather than at the western portal of the long tunnel, as proposed in my report of January 27, 1871, the cost of the water-line would be notably diminished. Further surveys are necessary, and other considerations will come in, (partly of an engineering and partly of a politico-economical character,) for the final determination of this question of method and scale of construction.

The following resolution was agreed to by four of the five members of the board:

Resolved, That, in the opinion of the board, the water-line by the James River and the Kanawha route, with 7 feet depth, may be completed in six years, at a cost of not more than $60,000,000, allowing an unusually broad margin for contingencies, which cannot be accurately measured. The cost may reasonably be expected to be within $55,000,000, and possibly will not exceed $50,000,000.

It was understood that the dissenting member objected to that part of the resolution which referred to the cost and time of completion of the work. The views of other members than myself as to probable cost will no doubt be stated in their separate opinions.

On this subject I submit the following: To my report of January 27, 1871, is appended Mr. Turpin's estimate for the enlargement of the existing canal, which contains an item of $1,300,000 for a dock and ship-lock at Richmond, in addition to a tide-water connection for the canal proper. This item may, it would seem to me, with propriety be omitted from the estimate for the through water-line. The total of the estimate of Messrs. Hutton and Turpin for the whole route was $47,600,000, containing an item of 10 per cent. for contingencies. Deducting the amount of the estimated cost of the ship-lock, $1,300,000, the total estimate would be reduced to $46,300,000. Increasing this by an amount equal to nearly an additional 10 per cent., or, in fact, giving a margin for contingencies of nearly 20 per cent., we reach the sum of $50,000,000, stated by me as the probable cost of the line.

The plan of the tunnel submitted in my report of January 27, 1871, contemplated a cross-section of 52 feet width and 34½ feet height. I now adopt the opinion of the board that it is expedient (as a first construction at least) to use a tunnel of less width, providing passing-places at suitable intervals.

This reduction in size will reduce the cost of the tunnel, whatever scale of prices be adopted for the work.

One colleague, Mr. B. H. Latrobe, whose great experience in tunneling entitles his opinions to the highest consideration, has revised the estimates for the tunnel, and I am willing to defer entirely to his judgment in that matter; yet I feel bound to ask attention to the circumstances which governed in fixing the scale of prices adopted in the estimate prepared by Mr. Hutton. (See his report with mine of January 27, 1871.) Besides relying upon his own excellent judgment and considerable experience, he took the advice of the engineers of the Chesapeake and Ohio Railroad, who had driven a long tunnel in close proximity to the site of that proposed for the canal. In the opinion of the chief engineer of the Chesapeake and Ohio Road, Mr. H. D. Whitcomb, (see his testimony before Senate Special Committee on Transportation,) the prices used by Mr. Hutton were sufficient. They were more than work of a similar character had been actually done for on the railroad. But, as stated before, I waive this point altogether, in deference to Mr. Latrobe's opinion.

If the canal be substituted for the slack-water navigation as far down as the Great Falls of the Kanawha, the estimate will be still further reduced. The existence of the Chesapeake and Ohio Railroad and of the James River Canal, by the facilities afforded for the transportation of materials, will make the cost of the improvement much less than it would otherwise have been. The price of labor in that section of country is low, as has been fully demonstrated by the cheapness of the excellent work done upon the tunnels and other portions of the railroad.

As to the annual expense, the board agreed unanimously to the following resolution:

Resolved, That, in the opinion of the board, the cost of maintenance of the water-line (repairs and administration included) should not exceed $1,000,000 per annum.

Mr. Lorraine, for many years the chief engineer and superintendent of the James River Canal, estimated the cost of maintenance of the water-line as about $400,000 per annum. Mr. Hutton, lately chief engi-

neer of the Chesapeake and Ohio Canal, estimated the cost of maintenance of the water-line at something less than $400,000. The experience of the Erie Canal is that the cost of maintenance is between one and two per cent. of the total cost. While agreeing with the board that the cost of maintenance of the water line *should not exceed* $1,000,000 *per annum*, I feel confident it need not, under proper management, exceed $750,000.

Finally and summarily, my opinion is, that it is entirely practicable to connect the waters of the James and Ohio Rivers by a canal and slack-water navigation of 7 feet depth. The cost need not under any circumstances, it seems to me, exceed $55,000,000, probably not $50,000,000, if the work be in the hands of honest and competent engineers, free from improper influences, and supplied with funds as fast as required. Under the same circumstances the work may be practicably completed in six years. The portions to the east and west of the long tunnel may be ready for use in four years, or sooner.

The line should not be regarded as a rival of the Erie Canal and Hudson River route, or of the Mississippi River route. They are necessary, and so is this as an intermediate and supplementary route. They will not be rivals, but all are now actually needed to do the pressing work of the people. As these wants increase, other similar lines will become equally necessary, and will be constructed.

While I think there is at command enough information to justify the opinions given above, I desire emphatically to recommend an early re-examination of nearly the whole route. Especially and first should this be done to determine positively the best location for the long tunnel, which will take more time for construction than any other part of the line, and there should be no delay in commencing it, if the work is to go on at all. The remaining portions of the work might be commenced two years later.

It is perhaps proper to repeat and emphasize the fact that the additional surveys required are not for the purpose of demonstrating the practicability of the work from end to end, but, by gaining more minute knowledge of the features of so long a line, to locate its details with precision, and thereby improve and cheapen its construction.

At present the estimate is an approximation, with a very broad margin on the side of fullness.

With further surveys the basis will be provided for a close estimate, which we would expect to be materially lessened from its present total.

Very respectfully, your obedient servant,

W. P. CRAIGHILL,
Maj. of Engineers, Bvt. Lieut. Col., U. S. A.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

5.—*Letter to the Chief of Engineers of General G. Weitzel.*

NEW YORK, *March* 18, 1874.

GENERAL: In addition to that which is said in the unanimous report of the board on the James River and Kanawha Canal, I desire to say that I believe the entire project, as presented to us for report, is practicable.

The only portion of the proposed manner of communication, about which, in the mind of one of the members of the board, the question

of practicability has not been settled, is the contemplated slack-water improvement of the Greenbrier, New; and Kanawha Rivers to Paint Creek Shoals.

But these rivers have been repeatedly as carefully examined and surveyed as the available time and funds would permit. The last one was made by Mr. Lorraine, in 1872, under the direction of Major Craighill, Corps of Engineers. "The object of this survey was chiefly to make a detail location of the locks and dams and a more accurate estimate of the cost of the work, and also to ascertain to what extent the Chesapeake and Ohio Railroad and the water-line would conflict with each other."

This duty was faithfully performed, and with as much detail as the funds allotted for the purpose permitted. One hundred pages of manuscript, containing details of descriptions of dams, &c., are omitted from the published report, but were before the board.

The location of the dams, in every instance, was made with the view of avoiding, as far as possible, without making too great a sacrifice of the interests of the water-line, all interference with the railroad. This result was accomplished by increasing somewhat the number of the dams, and placing some in somewhat unfavorable locations. It is further seen from this report that of the fifty-four dams required for this work between Howard's Creek and the Great Falls of the Kanawha, forty-two are located on solid rock, and that twelve are located on gravel and bowlder foundations. Not one of the numerous able engineers who have surveyed and examined this part of the work heretofore has expressed any opinion that it will be impossible to do it. It is admitted by all, that between Boyer's Ferry and the mouth of the Gauley River, owing to the contraction of New River and the increased velocity of the stream, the work will be more difficult and expensive than at other portions of the work.

The opinion of these engineers that this part of the route is practicable is corroborated in the strongest language by at least one very experienced builder of locks and dams, who is thoroughly acquainted with this locality.

This, together with the personal inspection of the localities made by the board, leads me to the opinion that this part of the work is practicable. It may, however, appear by additional surveys that some portions of this particular part of the improvement can be bettered by additional canals and tunnels, and this at probably not too large an extra expense.

Major Craighill, who was in charge of the recent surveys of this work, requested the sum of $25,000 to make further examinations, as appears from his official reports.

I am of the opinion that the whole of the Kanawha River, from the Great Falls to its mouth, should be improved by locks and dams throughout, or on the second plan suggested by Mr. Lorraine. I believe that this will be more reliable than the method by open sluice-dams, and that this element of certainty warrants the additional expense which this plan will entail. It has been a perfect success on the Monongahela River, and would be of great value as an additional experiment to decide the proper plan to be adopted for the improvement of the Upper Ohio River.

With regard to the cost of the improvement, I desire to say that the work of revising the estimates was placed in the hands of a sub-committee, of which the eminent civil engineer who was associated with us was a member. He naturally did most of the work of this sub-

committee, and made a report indorsing, in general, the sufficiency of the estimates.

In addition, the board was accompanied on its personal inspection of portions of the line by the chief engineer of the Chesapeake and Ohio Railroad, the superintendent and chief engineer of the James River and Kanawha Canal, and by a contractor on the railroad of long experience in similar works in the locality of the proposed water-line.

All have had the experience so valuable to decide this point, and all agree that the work can be done, if properly conducted, for the prices stated in Major Craighill's official report; that is, $50,000,000, in round numbers.

I believe this to be true; yet I admit, with three other members of the board, that a change in the plans, which might be decided upon after further surveys, might increase the cost of the work to fifty-five or even sixty million dollars.

But, in my opinion, even if it should cost five millions more than the extreme figure mentioned, it should be built, on account of the great benefit it would prove to the country, as will be seen from the following:

Its capacity is stated by Mr. Hutton as follows:

> On the Erie Canal, 198 boats have actually been passed through a single lock in one day. We may then safely assume a capacity for 180 boats. The tonnage of the boats which will be used will be about 280 tons; but, as the freight going West will not be more than one-fourth of that from the West, we will average them at 180 tons, which will allow a trade of 9,720,000 tons per annum, or for a season of 300 days.

A canal of this capacity can, therefore, do the work for at least three first-class railroads, but has the great advantage over the latter that it does the work so much cheaper.

The average per ton per mile carried by the Erie Canal in 1869 was one cent. The average on the New York Central and Erie roads was 2.68½ cents. This undoubtedly included through and way freights. I believe it, at the present day, a comparison somewhat unjust toward canals to say that a ton of through-freight can be carried a mile by rail for one cent, and by canal for one-half cent.

Now, supposing the three railroads built, and assuming that they were only two-thirds as long (about four hundred miles) as this improvement, and supposing the difference in cost of transportation per ton per mile were only one-half cent, and the whole line were a canal, the saving in freight in one year by the water-line to the commerce of the country, if it carried less than two-thirds of its capacity, (say 6,000,000 tons,) would be as follows:

By rail, 6,000,000 tons, 400 miles, at 1 cent per ton per mile	$24,000,000
By James River and Kanawha Canal, 6,000,000 tons, 602 miles, at ½ cent per ton per mile	18,060,000
Saving in one year	5,940,000

or nearly $6,000,000, or about one-tenth of the extreme estimated cost of the work.

This, to some, would probably appear astounding. But the history of the Erie Canal shows the value of such improvements. The cost of this canal up to 1863, with enlargement, was $38,977,831, which sum with interest had amounted to $52,491,915. Its gross earnings during the same period were $71,783,676; its expenses, $12,578,860; its net earnings were therefore $59,264,812, or nearly $7,000,000 above its cost, with interest. The amount of freight shipped by this canal in 1868 was 6,442,225 tons, so that I do not think I assume too much when I estimate the amount

of freight per annum on the proposed improvement at 6,000,000 tons, especially when it is borne in mind that this will on an average be used two and a half months in the year more than the Erie Canal.

But in another greater way it benefits the commerce of the country. It is a well-known fact that only a short period after the grain of the Northwest is ready to be shipped to the eastern markets the Erie and Canadian Canals freeze up and navigation on the lakes is suspended. Only a small portion of the immense products of the West have reached the sea-shore. The rail can only transport a small portion of the remainder. The farmers who can hold their crop until spring are affected only in losing the interest on the value of their property; but the mass of them, who cannot do this, must sacrifice their best interests to meet current expenses and payments, while at the same time the consumer at the East is obliged to pay prices out of proportion with those received by the producer, because the present facilities for transporting property are inadequate. Now, just at this juncture the Ohio River and its tributaries receive their good boating stage, and this improvement would enable the continued shipment through nearly all the time the lake and Erie Canal route is closed. This would be a great benefit. Suppose, on account of the ice that might form in the river and canal, only 2,000,000 tons of wheat are thus delivered East. This would be about 60,000,000 bushels. Now, this amount of wheat arriving East at such a juncture would benefit the people at least to the amount of 25 cents per bushel, and also the farmers of the West the same amount. The benefit to the country each year would be, therefore, on this account alone, at least $30,000,000. But the ice in the river and canal will never cause much delay.

The greatest obstruction to this route will occur (until the Ohio River is improved throughout) when the river is at a low stage. This always occurs when the lakes and Erie Canal route are open. It averages about sixty days in a year. The obstruction to it by ice, at farthest, will not average more than fifteen days in each year; so that now, even with an unimproved Ohio, this projected work would give 9½ months of unobstructed communication between East and West, and during four and a half of the five months when the lake and Erie Canal route is closed. It would thus secure an almost uninterrupted communication between the producers and consumers; give stability to and cheapen freights and prices, and thus benefit to a very great degree the commerce of the country, both East and West.

I am, sir, very respectfully, your obedient servant.

G. WEITZEL,
Major of Engineers.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers.

Proceedings of a Board of Engineers constituted by Special Orders No. 17, from the War Department, dated Adjutant-General's Office, Washington, January 27, 1874.

RICHMOND, VA., *February* 5, 1874.

The board met at 10 a. m., all the members being present.

The order appointing the board was then read, and also the letter of instructions from the Chief of Engineers to Col. J. G. Barnard, of the Corps of Engineers; the letter from the Chief of Engineers to Mr. B. H. Latrobe, and a letter from the Hon. H. G. Davis, United States Senator, to the Hon. W. W. Belknap, Secretary of War.

A communication from Mr. H. D. Bird, of Petersburg, Va., to Colonel Barnard was

made to the board, which communication recommended making Petersburg, instead of Richmond, the eastern terminus of the canal.

Then, after a short discussion and consultation, the board proceeded to the examination of the canal in the immediate vicinity of Richmond, passing up through three locks to the Powhatan Iron-Works and back to the city. The board then adjourned to meet again next day to proceed with the examination.

RICHMOND, VA., *February* 6, 1874.

The board proceeded, at 10 a. m., to examine the locks of the canal from the basin to the river, and returned to the office of the James River improvement at 11.25.

The board then met, and the proceedings of the last meeting were read and accepted.

Major Craighill then submitted to the board a list of documents and maps to be placed before them for their information.

The board, after consultation, decided to visit Charleston, W. Va., as the initial point for the further examination of the route.

Major Gillmore submitted the following resolution to the board, which was adopted, viz:

Resolved, That W. C. Wickham, esq., president, and H. D. Whitcomb, esq., chief engineer of the Chesapeake and Ohio Railroad, be invited to accompany the board on their trip to Charleston and other points on the line of the James River and Kanawha Canal.

Major Gillmore then submitted to the board a second resolution, as follows, viz:

Resolved, That the board will meet in the city of New York to prepare their report, their time for meeting to be fixed after completing the examination of the line of the canal, or such portions thereof as they may decide to visit.

This resolution was adopted.

The board then adjourned to meet a committee of the general assembly of the State of Virginia, which was appointed to tender certain courtesies on behalf of the State.

At 8.45 p. m. the board took their departure for Charleston, W. Va., arriving there about 3.30 p. m on the 7th.

The board left Charleston at 9 a. m. on the 9th for the examination of the route eastward, stopping at Cannelton and the Great Falls of the Kanawha, and examining the Great Bend tunnel of the Chesapeake and Ohio Railroad, and arrived at the White Sulphur Springs about 5 p. m.

The examination of the route from the Great Falls of the Kanawha to the *débouché* of the proposed tunnel, near Howard's Creek, was continued in detail, the train moving at a slow rate of speed for that purpose.

FEBRUARY 10, 1874.

The board left White Sulphur Springs about 1 p. m., and examined the Alleghany tunnel of the Chesapeake and Ohio Railroad, the locality of the eastern end of the proposed tunnel for the James River and Kanawha Canal, and the Lewis tunnel of the Chesapeake and Ohio Railroad, and stopped a few moments at the crossing of Brush Creek.

Resolutions were adopted appreciative of the courtesy of General W. C. Wickham, president of Chesapeake and Ohio Railroad; Mr. H. D. Whitcomb, chief engineer Chesapeake and Ohio Railroad; Colonel C. S. Carrington, president of James River and Kanawha Canal; Mr. J. H. Harris, chief engineer of James River and Kanawha Canal, and Mr. William R. Hutton, the first for having provided a special train for the use of the board, and the others for accompanying them on their examination of a portion of the route of the James River and Kanawha Canal.

The following resolution, submitted by Major Weitzel, was adopted by the board, viz:

Resolved, That Mr. B. H. Latrobe and Major Craighill be appointed a sub-committee to examine and revise the estimates of cost of the proposed line of water-communication between the James River and the Ohio, and that they are hereby requested to make a report of such examination and revision at the meeting of the board in New York City.

Goshen, Va., was reached about 5 p. m., where the board remained for the night.

FEBRUARY 11, 1874.

The board left Goshen, Va., at 9 a. m., all the members proceeding to Lynchburg, Va., via Charlottesville, Va., with the exception of Major Weitzel, who proceeded direct to Richmond, Va., thence to his station at Detroit, to await the call of the president for the meeting in New York.

Major Gillmore and Lieutenant Turtle at once proceeded to Richmond by the canal, Colonel Barnard, Mr. Latrobe, and Major Craighill remaining in Lynchburg.

FEBRUARY 12, 1874.

Colonel Barnard, Mr. Latrobe, and Major Craighill made an examination of the canal as far westward as Judith Pond, eight miles from Lynchburg; Colonel Barnard proceeded to New York; Major Gillmore and Lieutenant Turtle were *en route* to Richmond.

FEBRUARY 13, 1874.

Major Gillmore and Lieutenant Turtle reached Richmond about 6 a. m.; Mr. Latrobe and Major Craighill left Lynchburg for Richmond, Va., by the canal; Major Gillmore left Richmond for his station, to await the call of the president for the meeting in New York.

FEBRUARY 14, 1874.

Mr. Latrobe and Major Craighill were *en route* to Richmond, Va., by canal.

FEBRUARY 15, 1874.

Mr. Latrobe and Major Craighill arrived in Richmond about 6 a. m.

FEBRUARY 16, 1874.

Mr. Latrobe and Major Craighill, after an examination of Dutch Gap, proceeded this evening to Baltimore, Md., and Lieutenant Turtle, on the following day, to Old Point Comfort, Va., to await the call of the president for the meeting in New York.

Approved.

J. G. BARNARD,
Col. Engineers and Bvt. Maj. Gen., President of the Board.

THOMAS TURTLE,
First Lieut. of Engineers, U. S. A., Recorder.

Proceedings of Board of Engineers on the James River and Kanawha Canal, at the session in New York City.

NEW YORK, *March* 9, 1874.

The board met at 10.40 a. m., in accordance with the call of the president, all the members and the recorder being present.

The record of proceedings from February 6 to the departure of the several members to their stations, was read and accepted.

Mr. Latrobe and Major Craighill were called upon for a report of their examination and revision of the estimates of the cost of the proposed improvement. A verbal report was made to the effect that no written statement had been prepared, "as it was supposed the estimates might call for a good deal of discussion." Mr. W. G. Turpin, who made the survey from Richmond to the mouth of the Fork Run, under the direction of Major Craighill, had been examined, and his estimates had been taken as correct, and believed to be so.

Mr. W. R. Hutton, who made the survey of the proposed route from the mouth of the Fork Run to the mouth of Howard's Creek, which includes the tunnel, had been questioned on his estimates. To enable them to judge further upon the estimates for this portion of the line, they had gone to the Hoosac tunnel, and are expecting a report on estimates from Frost, the chief engineer.

"The estimates of quantities and prices from Howard's Creek were examined, and Mr. J. H. Harris, who was employed on the survey, and who prepared the report after the death of Mr. E. Lorraine, was questioned relative to these quantities and prices, and they were generally taken as correct. Exceptions were made in regard to contingencies, which would be very indeterminate. When Mr. Frost's letter will be received, they will be prepared to make a written report, should it be so desired."

Mr. W. G. Turpin, who had signified his intention to appear before the board if so required, was informed by telegraph that his presence would not be necessary, in words as follows:

Mr. W. G. TURPIN,
317 *Cary Street, Richmond, Va.:*

The board is satisfied with Mr. Latrobe's report of your estimates. Your coming on is, therefore, not necessary.

THOMAS TURTLE,
Lieutenant of Engineers, Recorder.

Mr. J. M. Harris, chief engineer of the James River and Kanawha Company, was then called before the board. His report to Major Craighill, dated Richmond, Va., April 1, 1873, was read in his presence, and explanation of the various matters contained in said report obtained from him. The examination of the report was contin-

ued from the initial point of Mr. Harris's survey at the mouth of Howard's Creek, to include dam No. 38 at the mouth of the Gauley; when, at 3.40 p. m., the board adjourned to meet to-morrow, March 10, at 11 a. m.

MARCH 10, 1874—11 a. m.

The board met pursuant to adjournment.

The report of proceedings of yesterday was read.

It was suggested by Major Craighill that, as Mr. Turpin's name was mentioned in connection with his work, Mr. Harris and Mr. Hutton receive like attention.

This change being introduced, the report was accepted.

A letter from Major Craighill to General Barnard, dated February 17, 1874, was read, and ordered to be inserted as part of the records of the board. The letter is as follows:

UNITED STATES ENGINEER OFFICE,
Baltimore, Md., February 17, 1874.

GENERAL: Before the board proceeds to the examination of the maps and drawings connected with the enlargement of the existing canal, known as the James River and Kanawha, and its extension, so as in connection with the Greenbrier, New, and Kanawha Rivers, to become what is called the "central water-line," I wish to call attention to the fact that, while I deem the data collected and the surveys made at the time of my report, as well as at this time, sufficient to warrant the opinion that it is practicable, at a cost of about $50,000,000, in six years, if the funds be supplied as fast as needed, to make a water-line of seven feet depth of water, with dimensions of locks, &c., as given in my reports and the sub-reports thereto attached, I by no means wish to be understood as submitting other than suggestions and approximations as to details and definitive location; these approximations, being as near the truth as possible—the effort having, however, always been to have the estimates so full and ample as to cover contingencies of changes, &c. Neither the time nor the means at my disposal have allowed anything more, and in this connection I desire especially to ask attention to the closing paragraph of my report of January 27, 1871, which is in the following words: "Should it be decided by the national authorities to proceed with this work, additional surveys will be necessary for the definite determination of the location in detail. These surveys should be immediately undertaken, and a sum not less than $25,000 should be appropriated for them." No such sum has since been at my disposal.

Very respectfully, your obedient servant,

WM. P. CRAIGHILL,
Major of Engineers.

General J. G. BARNARD,
President Board of Engineers.

Mr. Harris being again before the board, the estimates of the different dams, and of the Great Bend tunnel as an alternative proposition, were examined in detail.

The reading and examination of Mr. Harris's report was completed at 3.30 p. m.; the board adjourned to meet to-morrow, March 11, at 11 a. m.

MARCH 11, 1874—11.15 a. m.

The board met pursuant to adjournment.

The report of proceedings of yesterday was read, and, after some change in the phraseology, was accepted.

Mr. W. R. Hutton was before the board. His report of December 28, 1870, to Major Craighill, was read in his presence, and various questions were asked him relative to different portions of the same. The examination of this report was completed, and at 3.15 p. m. the board adjourned to meet to-morrow, March 12, at 11 a. m.

MARCH 12, 1874—11.10 a. m.

The board met pursuant to adjournment.

The report of proceedings of yesterday was read.

Mr. W. R. Hutton and Mr. J. M. Harris were before the board. Mr. Hutton was retained until 1 p. m.

An examination of maps of the route from the eastern portal of the tunnel, eastward, was made.

At 2.30 p. m. the board adjourned to meet to-morrow, March 13, at 1 p. m.

MARCH 13, 1874—1.20 p. m.

The board met pursuant to adjournment.

The report of proceedings of yesterday was read and accepted.

Mr. Latrobe read to the board a written expression of opinions and suggestions, and submitted a sketch explanatory of certain propositions in regard to the tunnel.

Similar expressions of opinion were read by the other members of the board.

Adjourned at 3 p. m., to meet to-morrow at 11 a. m.

MARCH 14, 1874—11.30 a. m.

The board met pursuant to adjournment.

The report of proceedings of the previous day was read and accepted.

Colonel Barnard and Mr. Latrobe read some remarks additional or supplementary to their written opinions of yesterday.

A series of resolutions was then offered as follows:

No. 1. Offered by Major Craighill:

Resolved, That while the board is of opinion that for ordinary passenger travel and many kinds of freight the railroad will be properly preferred as to the means of transportation, there can be no reasonable questioning of the fact that when the circumstances are such that comparative slowness of movement is permissible, and the quantities to be moved large, the cheapness of transportation by water becomes obvious to every one who fairly weighs the statistics on the subject. In this view very great benefits to commerce would be derived from the construction of a water communication from east to west between the James and Ohio Rivers.

This resolution was adopted unanimously.

No. 2. Offered by Major Craighill:

Resolved, That the board is of opinion that it is entirely practicable to drive the long tunnel through the Alleghany Mountain, by which it has been proposed to connect the headwaters of the James and Greenbrier Rivers. The cost of such a tunnel, 34 feet in clear width, with passing-places for boats each one-fourth of a mile, would be about $2,000,000 per mile. The time of execution need not be over six years.

This resolution was adopted unanimously.

No. 3. Offered by Major Craighill:

Resolved, That the board is of opinion that by the use of reservoirs on Anthony's Creek and the Greenbrier River a sufficient supply of water may be had for the requirements of the tunnel summit-level and its dependencies, and that the supply of water is also sufficient for the portions of the proposed water-line east and west of the high level.

This resolution was adopted unanimously.

No. 4. Offered by Major Craighill.

Resolved, That the board is of the opinion that it is entirely practicable to enlarge the existing James River Canal, making the locks 120 feet by 20 feet, and the width of the canal at the water-line 70 feet, with a depth of 7 feet; and to extend the canal and slack-water navigation of the same dimensions to the eastern portal of the long tunnel, thus admitting the use of boats of 250 tons burden.

This resolution was adopted unanimously.

No. 5. Offered by Major Craighill:

Resolved, That, in the opinion of the board, the preparation of the Kanawha River for navigation from the Ohio to the Great Falls of the Kanawha for boats of 700 tons is entirely practicable.

This resolution was adopted unanimously.

No. 6. Offered by General Barnard:

Whereas there are differences of opinion among members of the board as to the practicability of lock and dam (or "slack-water") navigation of the Greenbrier and New Rivers, between Howard's Creek and the Great Falls of the Kanawha; and whereas the same differences prevail as to the extension of the barge-navigation of the Kanawha above the Great Falls:

Resolved, That, in the opinion of the board, it may be expedient to adopt canal navigation for this part of the line, with occasional exceptions, where it may be desirable in consequence of peculiarly favorable reaches or the necessities of water-supply.

This resolution was adopted unanimously.

No. 7. Offered by General Barnard as supplementary to No. 1:

Whereas the James River and Kanawha route being among the few south of the Erie Canal route over which it appears practicable to establish a water-navigation connecting by the Ohio the immense internal navigation of the Great Mississippi Valley with the sea-ports of the Atlantic; and whereas it will probably furnish the most direct connection; and whereas the route has very great local advantages of climate, owing to which it will be comparatively little obstructed by ice, and of a *geological character* connecting the richest coal-fields of the world, now lying almost undeveloped for want of adequate means of removal, with the markets of the world, and at the same time with the almost equally rich region of iron and other ores in the Virginia Valley: Therefore,

Resolved, That, in the opinion of the board, this route presents extraordinary claims as the measure of relief to the population of the Western States, in furnishing them for their bulky productions cheap transportation to a market and for fostering the commerce of the United States by developing immense mineral resources now neglected.

This resolution was adopted unanimously.

No. 8. Offered by Major Craighill:

Resolved, That, in the opinion of the board, the cost of maintenance (repairs and administration included) of the water-line should not exceed $1,000,000 per annum.

This resolution was unanimously adopted.

No. 9. Offered by Major Craighill.

Resolved, That while the estimates have hitherto been limited to a water-line with canal-locks 120 feet by 20 feet, and slack-water of 240 feet by 40 feet, the board is of opinion that the canal-locks should be built of 23 feet to 24 feet width, with a corresponding increase in the width of the slack-water locks, with a view to increased capacity for the line in future, if demanded, as this additional width can be economically given. Additional depth could thereafter be readily obtained to as great an extent as the water-supply would permit by raising the walls and banks.

This resolution was adopted, Colonel Barnard voting in the negative.

No. 10. Offered by Major Craighill:

Resolved, That, in the opinion of this board, it is entirely practicable to connect the waters of the James and Ohio Rivers by a water-navigation 7 feet in depth.

Adopted unanimously.

No 11. Offered by Major Craighill:

Resolved, That, in the opinion of the board, the water-line by the James River and Kanawha route, with 7 feet depth, may be completed in six years, at a cost of not more than $60,000,000, allowing an unusually broad margin for contingencies, which cannot be accurately measured. The cost may reasonably be expected to be within $55,000,000, and may possibly not exceed $50,000,000.

This resolution was adopted, Colonel Barnard voting in the negative.

No. 12. Offered by Mr. Latrobe:

Whereas the time within which the line of this improvement can be opened to the trade of the West, so urgently demanding a new outlet to the seaboard, must depend upon the completion of its most difficult work, the earliest possible commencement of the long Alleghany tunnel is highly desirable, and is earnestly recommended by the board, while surveys for the definite location for the whole line of the improvement should be also begun without delay, in order that all the questions relating to its plan may be determined in time to avoid delay in its completion simultaneously with the tunnel.

This resolution was adopted, Colonel Barnard voting in the negative.

The board adjourned at 3.30 p. m., to meet Tuesday, March 17, at 11 a. m.

MARCH 17, 1874.

The board met at 1.20 p. m., the time of meeting having been postponed by the president from 11 a. m., as the general report in preparation by him was not yet completed.

The record of proceedings of March 14 was read and accepted.

The general report was then read by the president and adopted by the board.

The following resolution was presented by Mr. Latrobe and adopted by the board, viz:

Resolved, That the board tender their thanks to their president for the clear, concise, and able manner in which he has embodied their views in the report which he has just read.

A resolution was then presented by Major Craighill, as follows:

Resolved, That the board, when it adjourns to-day, meet on the 19th, at 1 p. m., when the separate papers of the members will be submitted and read before the board, to be thereafter, as soon as practicable, sent to the Chief of Engineers with the general report.

This resolution was adopted, and at 2.30 p. m. the board adjourned, in accordance with the terms of the resolution.

1.15 P. M., MARCH 19, 1874.

The board met pursuant to adjournment. Major Weitzel was absent, he having been excused from further attendance by the president after the presentation of his special remarks yesterday.

The record of proceedings of March 17 was read and accepted.

The general report was again read and the signing of the same completed, Major Weitzel having previously signed it.

The special remarks of the several members were then read, and at 4.15 p. m. the board adjourned *sine die*.

Approved.

J. G. BARNARD,
President of Board.

THOMAS TURTLE,
First Lieutenant of Engineers, Recorder.

NOTE.—Colonel Barnard states that declining to vote, rather than a negative, would better express his opinion on resolutions 9 and 12.

APPENDIX V.

ANNUAL REPORT OF LIEUTENANT-COLONEL J. D. KURTZ, CORPS OF ENGINEERS, FOR THE FISCAL YEAR ENDING JUNE 30, 1874.

UNITED STATES ENGINEER OFFICE,
Philadelphia, Pa., July 18, 1874.

GENERAL: I have the honor to transmit herewith the reports of river and harbor works in my charge for the fiscal year ending June 30, 1874.

Very respectfully, your obedient servant,

J. D. KURTZ,
Lieut. Colonel of Engineers.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

V 1.

CONSTRUCTION OF PIER NEAR LEWES, DELAWARE.

At the close of the fiscal year the pier had been extended out to 1281 feet from its beginning, into water of the depth of 15.5 feet at low-water. The bridge-way of the pier is 1,155 feet long, and is three piles and 22 feet wide; the pier-head is five piles and 43 feet wide. Of the pier-head, 186 feet of the iron-work have been constructed. Thirty pile-shafts, 8½ inches diameter and 54 feet long, are on hand for the continuance of work, with the necessary screws, caps, braces, &c., and also timber for the floor of the entire structure.

The year's work consists in extending the pier from 1,155 feet to 1,281 feet length, and from 9.3 feet depth of water to 15.5 feet depth. Work was suspended in November last, when the appropriation was exhausted, and the property stored till the resumption of operations.

The small appropriation of $10,000 made for the service of the present fiscal year will be applied to inserting the piles now on hand, with their connecting parts, and placing the timber-work upon them. If any balance of funds remains, it is proposed to use it in fitting the pier temporarily for use of vessels.

It is a source of regret that the efforts to place the current-dynamometers in working condition failed. The information they would afford is valuable; the investigation is novel on our coast, and our possession of wind-measuring apparatus at the locality would afford the special opportunity of making direct comparison of the velocity and continuance of wind-currents with the corresponding movements of the sea.

Should Congress, in conformity with their determination in voting $225,000 for the commencement of this work, now appropriate the means necessary to finish it, the pier can be completed without unnecessary delay. It will be the first structure of the kind in our waters. It will be a valuable adjunct to the use of the great harbor of refuge in which it is placed, and will afford an important outlet to the commerce of the Delaware region, as well as facilitate materially the operations of the Navy in case of war.

The accompanying report of Capt. M. R. Brown, Corps of Engineers,

the officer in immediate charge of the construction, affords full details of the history of the work for the year.

The detached statement of the original estimate for this work, with the reasons for an increase thereof, is sent herewith.

The amount required to complete this work is..... $176,500

Financial statement.

Balance in Treasury of United States July 1, 1873.....	$8,000 00
Amount in hands of officer and subject to his check, (including $32,377 percentage due on contracts not yet completed).....	39,268 12
Amount appropriated by act approved June 23, 1874	10,000 00
Amount expended during the fiscal year ending June 30, 1874	47,268 12
Amount available July 1, 1874	10,000 00
Amount required for the fiscal year ending June 30, 1876.....	176,500 00

Report of Capt. M. R. Brown, Corps of Engineers.

PHILADELPHIA, PA., *July* 18, 1874.

SIR: Excepting the operations in the early part of the current fiscal year, work on the pier has, to a considerable extent, been routine in character.

At the beginning of July fifty-five rows of piles were in place, and fifty bays of superstructure were completed. The work next in prospect presented new conditions, imposed by a bottom of constantly increasing softness, compelling a resort to the firm gravel about 25 feet below the bed of the harbor, in order to secure a safe foundation, thus constraining us to use piles much longer and heavier, until at last, instead of piles 16 feet long and about 5 inches in diameter, weighing 1,600 pounds, such as were used in the earlier portions of the work, we were compelled to deal with solid iron columns, more than 54 feet in length and over 8 inches in diameter, weighing about 10,000 pounds.

One point of great importance deserves mention here. The gravel stratum, on which alone dependence is placed as an ultimate foundation for the outer portion of the pier, is so hard and impenetrable that it is doubtful whether or not the foundation-screws could possibly be forced into it their own depth; and yet it would be fatal to rely on any other stratum than this to uphold even the ordinary prospective loading of the pier. This gravel stratum is reached at various depths below the water-surface, and had not great precaution been taken some of the screws would have rested in a semi-liquid alluvial mud, while others could not have been driven far enough into the gravel to avoid the necessity of taking up the piles and sending them to the contractor's shops to be cut shorter and to have the necks turned off anew. The wisdom of the careful preliminary reconnoissance of the bottom, including the sinking of artesian tubes, is therefore clearly shown.

Very early in the season we came upon mud, with sand, in such proportions as to present very little opposition to the insertion of screw-piles. Here the use of the water-jet was found unnecessary. A short distance beyond our operations were no longer aided by using the water-jet.

It is evident, then, that the device is useful in a great degree only in hard and compact sand. It may fairly be doubted whether or not the first thousand feet of the pier could have been built in accordance with the project without the application of water-jets to the upper surface of the flanges of the screws. The work thereby eliminated from this portion of the project amounts to more than nine-tenths of the whole labor involved in screwing down piles by a direct application of power alone. We were also enabled to settle the screws as deeply as we chose in a bottom where the strongest iron screws were broken as though they had been of glass when main force alone was used in an unsuccessful effort to sink them more than 4 feet.

The derrick erected for use in putting down the largest piles has proved as successful as was expected or desired, and no difficulties or impediments have been met with except those which patience and perseverance have cleared away or conquered, easily if not always hastily.

Progress outward has of late been slow, necessarily, compared with the advance made in the earlier part of the work, for the following reasons mainly, which need mention only for the information of those who are unacquainted with the work.

Each pile of the outer portion of the pier weighs more than six times as much as the lightest ones of the inner portion.

The piles of the outer portion must be inserted at points distant from the storage ground.

Each outer row contains five piles to three in each row of the bridge part.

The outer piles must go down 24 feet into the bottom, and through about the same depth of water.

The inner piles are inserted only 10 or 12 feet in sand, covered by two feet of water. On the other hand, a progress of 21 feet, or one bay, now adds from six inches to nine inches to the depth of water at the pier-head, already 16 feet at low-water, while, at an earlier stage, we were merely reaching outward to render available the portion now under construction.

It seems important that a clear understanding of the present status of the work should be had by the public interested, lest they may be led to anticipate an unreasonable progress from the appropriation of $10,000 just made by Congress. Were we compelled to use this money for the purchase of material, it would buy only about ten piles, with their caps and screws. We have on hand, however, all the material that can be placed in the pier with the sum named.

When active operations were suspended last December, much of the material, such as rope, cable, &c., as well as the pontons in use, was in a greatly damaged condition. They might have been kept in use at that time, however, somewhat longer. It will now be necessary to purchase a large amount of new material in the place of that worn out, which would be unsafe if used after the deterioration it has sustained through wear and the effects of time.

It will also require the expenditure of considerable time and money to restore dismantled machinery, make necessary repairs, and generally to place the work in the condition of readiness in which it was last November, when, after the reception of the decision that the mules purchased from the appropriation for the pier could not be sold, in order that the proceeds might be used in continuing the work, it became necessary to discharge all employés as soon as practicable. The weather, as is usual in the vicinity of Cape Henlopen during the latter part of November, was so unfavorable that only an occasional day was suited to the sinking of screw-piles. The time was economically employed, however, in necessary work, including bracing, the storing of material, and making inventories thereof.

By the end of November the amount of money remaining to the credit of the appropriation for the pier was barely sufficient to cover the expense of maintaining a property-keeper until the 1st of July, 1874, besides provision for contingent and unavoidable items. Having ascertained through experience that to put the members of the derrick together and to fit it for work involves a considerable expenditure, I did not think it wise to incur the double expense of dismantling and refitting with so small a balance of money on hand. However, its portable parts, including the gearing, were taken from it and carefully stored. The same dearth of funds deterred me from doubtful and costly efforts to adjust the dynamometer in such a manner as to give reasonable hopes of obtaining valuable results during the winter.

The weather very rarely presents conditions of wind and water favorable for such work on an insecure raft, outside the protection of the breakwater. Guys were attached to the dynamometer-pile, and were well secured to the breakwater and to anchors beyond. The platforms containing the instruments had been secured in temporary positions on the pile, at a time when it was hoped that circumstances would allow me to have them fixed in their proper positions after the pile should be screwed down. Such days as promised success in this work were invariably consumed in the attempt whenever the condition of work on the pier would justify it. The fine mornings which tempted to this digression were generally the preludes to sudden squalls later in the day, and in such cases the raft with all on board was often saved from swamping only by great effort.

I regret to add that some time in December or early in January a schooner ran into the pile and bore it down so that it now lies flat on the bottom.

The wire-rope guy connecting it with the breakwater remains intact, but the others are not visible. Most of the employés engaged on the pier were discharged on the 13th of November, 1873. On the last day of November all were discharged excepting my draughtsman and assistant, Mr. Stierle, and Mr. D. H. Houston, clerk, both of whom remained employed until December 11. When the work of the season closed such property as required protection from the weather or thieves was securely stored in one or another of the buildings on the grounds.

At this time 61 rows of piles had been inserted, the last row 1,281 feet beyond the abutment.

There remain on hand 30 piles of uniform size, 8½ inches in diameter. With these are the corresponding caps and screws, besides 15 additional caps and the same number of supernumerary screws. All braces are in place and connected to the fifty-seventh row, inclusive. From the fifty-eighth to the sixty-first or last row, both inclusive, the braces are as indicated in an accompanying sketch. The braces remaining on hand

will suffice for the construction to the seventieth row, inclusive. Collars and turnbuckles will be exhausted with the completion of the sixty-seventh row.

It has been found unnecessary to adjust the screw-buckles of the braces for changes of season and corresponding variations of temperature, whose effect in producing expansion and contraction of the braces is very little. No strain on the members of the pier is apparent anywhere at any time. The lumber for the entire pier is on hand. Small amounts will be needed, however, in the course of construction at different times for subsidiary purposes.

I suggest the purchase of a number of wooden piles to serve temporarily as fenders, to be inserted at the last of the season's work, so that the pier, incomplete as it will be, may yet be used by vessels of moderate draught.

The lower layers of the piles of lumber are covered with sand during the winter. Most of it is generally blown away in the late spring.

A more serious effect of the wind is in the partial undermining of the foundations of the temporary buildings. These being wholly built on piles, are more or less threatened by the scattering of the sand from around the supports. This has been mostly prevented by placing obstructions to the free action of the wind in proper localities, and by spreading brush in other places so as to catch and retain flying sand. The foundations of the store-house, which contains much iron, must be carefully watched especially

There are six pontons belonging to the work now stored just above the highest water-mark. They have all been condemned, and are nearly worthless for use in the work. No reliance can be placed in them even after extensive repairs, and I recommend that four pontons as stanch as possible be procured in season for use when work on the pier is resumed.

The superstructure of the pier is complete to the fifty-fifth row, inclusive, or for a length of 1,155 feet. The longitudinal stringers are on the fifty-eighth row, and the cross-girders to the fifty-sixth row.

During the next few months it is proposed to extend the pier as far as the appropriation will allow, and if the measure is approved to prepare the end of the pier for such use as may be found practicable.

Very respectfully, your obedient servant,

M. R. BROWN,
Captain of Engineers, U. S. A.

Lieut. Col. J. D. KURTZ,
Corps of Engineers.

The original estimated cost as now being carried on is as follows:

	Designation.	Price.	Cost.
147 piles, 22′ x 5″ (and 5¼″,) (147 x 1,575) ..... pounds.	231, 525	.....	.....
16 piles, 27′.4 x 5½″ (and 5¾″,) (16 x 2,360) ..... do..	37, 760	.....	.....
10 piles, 31.28 x 6″ (and 6¼″,) (10 x 3,180) ..... do..	31, 800	.....	.....
125 piles, 54 x 8¼″ (and 8½″,) (125 x 10,246) ..... do..	1, 581, 835	.....	.....
298	1, 882, 920	$0 08	$150, 633 60
5 longitudinal braces, 23′ x 2½″, (5 x 23 x 16 55) ..... pounds.	2, 284	.....	.....
40 longitudinal braces, 24′ x 2½″, (40 x 24 x 16.55) ..... do..	15, 888	.....	.....
60 longitudinal braces, 25′.5 x 2½″, (60 x 25.5 x 20.03) ..... do..	30, 646	.....	.....
135 longitudinal braces, 27′.5 x 3″, (135 x 27.5 x 23.84) ..... do..	88, 506	.....	.....
240	137, 324	10	13, 732 40
223 cross-braces, 14′.5 x 2″, (223 x 14.5 x 5 x 10.59) ..... pounds.	34, 243	.....	.....
24 cross-braces, 14′.5 x 2½″, (24 x 14.5 x 11.96) ..... do..	4, 162	.....	.....
32 cross-braces, 14′.5 x 2¼″, (32 x 14.5 x 13.41) ..... do..	6, 222	.....	.....
48 cross-braces, 14′.5 x 2⅜″, (48 x 14.5 x 14.94) ..... do..	10, 398	.....	.....
112 cross-braces, 14′.5 x 2½″, (112 x 14.5 x 16.55) ..... do..	26, 877	.....	.....
8 cross-braces, 14′.5 x 2½″, (8 x 14.5 x 11.96) ..... do..	1, 388	.....	.....
32 cross-braces, 17′ x 2¼″, (32 x 17′ x 13.41) ..... do..	6, 975	.....	.....
48 cross-braces, 20′ x 2⅜, (48 x 20 x 14.94) ..... do..	17, 542	.....	.....
112 cross-braces, 22′ x 2½, (112 x 22 x 16.55) ..... do..	40, 779	.....	.....
639	148, 586	10	14, 858 60
879 screw-buckles, average 60 pounds each ..... pounds.	52, 740	25	13, 185 00
1,670 bolts and nuts, average 10 pounds each ..... do..	16, 700	14	2, 338 00
240 longitudinal and cross-brace collars, average 85 pounds each ..... pounds. 20, 400			
174 cross-brace collars, average 75 pounds each ..... do.. 13, 050			
	33, 450	11	3, 679 50

	Designation.	Price.	Cost.
298 cast-iron screws, average 305 pounds each..pounds. 90,890			
298 cast-iron caps, average 550 pounds each.....do.. 163,900			
	254,790	$0 06	$15,287 40
Receiving and putting down 298 piles.....days.	6,463	1 75	11,310 25
Blacksmith's labor.....do..	300	3 00	900 00
Adjusting caps and braces, (smithery).....do..	600	3 00	1,800 00
Adjusting caps and braces, (labor).....do..	840	1 75	1,470 00
Services of divers.....do..	420	9 00	3,780 00
Diving-apparatus.....	.....	.....	1,500 00
9,657 linear feet string-timbers, 12" x 12", board-measure. 116.0			
5,133 linear feet cross-timbers, 9" x 9".....do..... 34.6			
5,118 linear feet railroad-stringers, 8" x 10".....do..... 34.0			
32,932 linear feet floor joists, 9" x 4".....do..... 98.8			
23,160 linear feet floor-joists, 4" x 4".....do..... 31.0			
3,700 linear feet curbing, 6" x 4".....do..... 7.4			
72,694 linear feet planks, 3" x 6".....do..... 110.6			
	432.4	40 00	17,296 00
862 bolts through string-timbers, average 5.25 pounds...pounds.	4,500	12½	562 50
Other bolts and spikes.....do..	3,000	12½	375 00
4,200 linear feet rails, 20 pounds per foot.....do..	8,400	05	4,200 00
Constructing timber-top, (carpentry).....days.	1,000	3 00	3,000 00
Constructing timber-top, (labor).....do..	700	1 75	1,225 00
58 piles, averaging 25' x 3", (58 x 25' x 65.45) ...pounds. 94.902			
26 piles, averaging 33' x 5", (26 x 33 x 65.45)..... do.. 56.156			
110 piles, averaging 48'.3 x 5", (110 x 48.3 x 65.45) ...do.. 347.736			
	498,794	08	39,903 52
194			
70 fender-caps, 73 pounds each.....pounds.	5,110	11	562 10
18 fender-caps and rings, 105 pounds each.....do..	1,890	10	189 00
1,760 linear feet braces, 2 inches diameter, 10.47.....do..	18,427	10	1,842 70
88 screw-buckles, 50 pounds each.....do..	4,400	25	1,100 00
176 bolts and nuts, 6 pounds each.....do..	1,056	12½	132 00
194 cast-iron screws, 2 feet diameter, 300 pounds each.....do..	58,200	06	3,492 00
Receiving and putting down 194 piles.....days	2,100	1 75	3,675 00
Blacksmith's labor.....do..	230	3 00	690 00
Adjusting collars and braces, (smithery).....do..	50	3 00	150 00
Adjusting collars and braces, (labor).....do..	150	1 75	262 50
12 buoys.....	.....	50 00	600 00
Scow with pile-driver.....	.....	.....	1,800 00
Portable engine.....	.....	.....	1,500 00
2 boats.....	.....	.....	322 18
Labor in care of and repair of machinery.....days	2,000	1 75	3,500 00
Overseer.....months	24	120 00	2,880 00
Clerk.....do..	24	120 00	2,880 00
Draughtsman.....do..	24	120 00	3,800 00
Inspector.....do..	12	150 00	1,800 00
Stationery, office-rent, fuel, transportation, freight, postage.....	.....	.....	2,000 00
Add for unforeseen expenses, 10 per cent.....	.....	.....	33,329 62
Add amount expended for machinery, buildings, trials, and surveys.....	.....	.....	20,796 00
Total.....	.....	.....	387,419 67

Total amount appropriated since the adoption of the present project.....	$235,000 00
Total amount expended.....	225,000 00
Amount originally estimated to complete the work.....	152,419 67

An appropriation beyond this originally estimated cost is desired, for the following reasons, viz: increased price of iron and labor; the operation of the 8-hour law; the occurrence of a sunken wreck across the line of the pier; suspensions of the work, and strikes of the workmen.

The probable sum in addition to.....	$152,419 67
That will be required to meet these difficulties is.....	24,000 00
Making a total appropriation asked for of.....	176,419 67

V 2.

CONSTRUCTION AND REPAIR OF ICE-HARBOR PIERS AT NEW CASTLE, DELAWARE.

The small quantity of stone and timber that remained from the old pier in the middle of the harbor has been removed; the wood-work of

the old pier on the lower line of the harbor has been sheathed with oak and the corners protected with iron plates; a new pier, consisting of wooden-crib foundation to surface of low-water, and a stone superstructure, has been built (finished July 9) on the upper line, in about 27 feet water at low-tide, and a quantity of stone accidentally dropped within the limits of the harbor has been removed.

An appropriation of $10,000 has been made for the present fiscal year, which it is proposed to apply to the removal of obstructions in the harbor and the commencement of a new pier.

The design for the harbor includes two additional piers, which are estimated to cost $30,000 each = $60,000.

The original estimated cost of this work was:

To complete repairs of old pier	$7,000
For three new piers, at $20,000 each	60,000
Total	67,000

It has since been determined, in view of the greater depth of water and the exposure of the situation, to increase the size of the piers.

On issuing proposals for building a new pier it was found, accordingly, that, with the necessary contingent expenses, it would require $30,000 for each pier complete, instead of $20,000.

It was also found important to sheathe one of the existing piers and to remove the remains of another, which, with the removal of the stone before mentioned, were not included in the original estimate.

Therefore the original estimate of $67,000 is increased to the extent of $33,000.

Required to complete the ice harbor	$100,000 00
The whole amount appropriated to June 30, 1874, is	59,500 00
Amount expended to June 30, 1874, is	38,880 25
Amount required to complete the work	40,500 00

New Castle is in the collection-district of Wilmington, Del., which is also the nearest port of entry.

The revenue collected there for the year 1873–'74 was $20,255, and at Philadelphia $8,264,699.

Fort Delaware is the nearest fort, and Christiana light the nearest light-house.

Financial statement.

Balance in Treasury of United States July 1, 1873	$34,000 00
Amount appropriated by act approved June 23, 1874	10,000 00
Amount expended during the fiscal year ending June 30, 1874	22,000 15
Amount available July 1, 1874	14,947 65
Amount required for the fiscal year ending June 30, 1876	30,000 00

V 3.

IMPROVING HARBOR AT MARCUS HOOK, PENNSYLVANIA.

Since the completion of the ice-piers at this harbor, in 1871, no additional work has been done except to attach strong iron ladders, (one to each pier,) so as to afford access to the top of the piers.

The lower outer pier and the shore ice-pier, just west of the down-river landing, require repairs. The extent of the repairs requisite for the outer pier will probably be the resetting of a portion of the two upper courses, which have been somewhat disarranged by a large three-masted schooner coming in contact with it.

The old wooden landing-piers also require moderate repairs, such as

filling in between cap-logs, renewing the oak fenders, and floors to the bridges.

These repairs can be executed during the present season from the unexpended balance of the original appropriation.

Marcus Hook is in the collection-district of Philadelphia, Pa.; the nearest port of entry, light-house, and fort are, respectively, Wilmington, Del., Christiana light, and Fort Mifflin.

The revenue collected at Wilmington and Philadelphia during the fiscal year ending June 30, 1874, is, respectively, $20,255.09 and $8,264,699.53.

Financial statement.

Balance in Treasury of United States July 1, 1873	$10,462 12
Amount available July 1, 1874	10,462 12

V 4.

IMPROVEMENT OF WILMINGTON HARBOR, DELAWARE.

By the act approved March 3, 1873, an appropriation of $6,000 was made for the continuation of the improvement of this harbor, and by act approved June 23, 1874, a further appropriation of $6,000 was made for the same object.

Under the act of March 3, 1873, proposals were invited under date of June 21, 1873, and a contract was subsequently awarded to the American Dredging Company for the removal of about 100 cubic yards of rock from the channel of the river just below Third-street bridge. Owing to unavoidable delays and unforeseen difficulties at other works, the contractors were unable to commence rock operations at this locality until June 17, 1874. Since that time good progress has been made in drilling and blasting, and a portion of the rock has been removed. A contract was executed by the same company under date of September 13, 1872, for the removal of thirty-five cubic yards of rock on the south side of the channel about 600 feet above Third-street bridge. This work has been completed during the fiscal year.

Local surveys have been made of the Christiana River at different points between its mouth and Third-street bridge, and the information derived therefrom has been added to the chart of the river and harbor that is now nearly complete.

In view of the small amount appropriated for the improvement of the harbor for the fiscal year ending June 30, 1875, it is proposed to apply the same for the removal of additional rock from the south side of the channel just below Third-street bridge, to the amount of about 135 cubic yards. This improvement (which will be permanent) will give increased width to the channel, a better approach to the south draw-passage of the bridge, and afford thirteen feet depth of water at ordinary low-tide over the rock.

It is proposed to continue the improvement of this river during the next fiscal year by dredging, so as to afford 12 feet depth of water at ordinary low-tide, and increasing the width to 120 feet at the localities along the river and in the harbor, enumerated as follows, viz: In the channel just above the buoy-depot of the Light-House Establishment; opposite and below the mouth of Brandywine Creek; up stream from the north draw-passage of Third-street bridge; and adjacent to Market-street bridge, above and below. This will require in the aggregate about 53,000 cubic yards of excavation; 6,000 cubic yards of this amount will

be loose gravel and sand; the balance, soft mud. This work will require an appropriation of $20,000.

Population of Wilmington, Del., 39,000; present annual increase, 2,000.

The amount of capital employed in manufactures in the city of Wilmington and suburbs is $12,725,000. Value of manufactured articles, $21,150,000.

Wilmington is in the collection-district of Delaware, and is a port of entry. The nearest light-house and fort are, respectively, Christiana light and Fort Delaware.

The amount of revenue collected at Wilmington during the fiscal year ending June 30, 1874, is $20,255, and at Philadelphia $8,264,699.53.

Abstracts of proposals and of contracts are sent herewith.

Original estimate for improving Wilmington Harbor, Delaware.

1st. For removal of a rock in channel-way, as specified in report of November 2, 1870	$1,000
2d. For dredging a cut 120 feet wide, 12 feet deep at low-water, through the bar at the mouth of the river, 19,000 cubic yards, at 40 cents	7,600
3d. For dredging a cut 120 feet wide, 12 feet deep, through the shoal just below the Brandywine, 32,000 cubic yards, at 40 cents	12,800
4th. For dredging a cut 120 feet wide, 12 feet deep, above the Brandywine to the ship-yards, 48,000 cubic yards, at 40 cents	19,200
5th. For widening the cut at the light-house to 300 feet, 96,000 cubic yards, at 40 cents	38,400
Add for surveys, inspectors, office-expense, and contingencies	4,000
	83,000
Total amount appropriated to June 30, 1874	$37,000 00
Total amount expended to June 30, 1874	25,843 49
Amount required to complete the work	46,000 00

Financial statement.

Balance in Treasury of the United States July 1, 1873	$5,000 00
Amount in hands of officer and subject to his check	1,895 66
Amount appropriated by act approved June 23, 1874	6,000 00
Amount expended during the fiscal year ending June 30, 1874	1,739 15
Amount available July 1, 1874	11,156 51
Amount required for the fiscal year ending June 30, 1876	20,000 00

Abstract of proposals for improvement of Wilmington Harbor, Delaware, received and opened at 12.30 p. m. July 23, 1873.

No.	Bidder, name and residence.	Removal of rock, 100 cubic yards, net rate per cubic yard.	Begin—	Complete—
1	The American Dredging Company, Philadelphia, Pa	$37 50	Sept. 1, 1873	Dec. 1, 1873
2	Robert W. Warren, No. 7 Burling Slip, New York. (No guarantee.)	48 00	Sept. 1, 1873	July 1, 1874

Abstract of contract for improvement of Wilmington Harbor, Delaware.

Contractor.	Removing rock.	To commence—	To complete—
American Dredging Company, 10 South Delaware avenue, Philadelphia.	$37. 50 per cubic yard.	September 1, 1873	December 1, 1873

V 5.

IMPROVING CHANNEL OF SCHUYLKILL RIVER, PENNSYLVANIA.

By the act of March 3, 1873, $40,000 were appropriated "for the improvement of the channel of the Schuylkill River, Pennsylvania, of which amount a portion shall be used for commencing the removal of the rock at and near South-street wharf." Also, by act approved June 23, 1874, $20,000 were appropriated "for continuing the improvement of the Schuylkill River."

During the fiscal year ending June 30, 1874, the improvement of this river has been in progress at the following places, viz: at the bar just above Penrose Ferry bridge, at the south end of the bar below "Gibson's," at and near South-street wharf, and at Locust-street wharf.

Under an informal agreement with Mr. Wm. H. Beard, dated June 11, 1873, the work of removing the gravelly bar above Penrose Ferry bridge was commenced July 18 following.

Operations at this place continued without interruption, except a suspension during the winter months until May 16, 1874. During that time 97,493 cubic yards of material were removed, making one continuous cut for about 4,500 feet through the entire length of the bar, and a second cut from near "Penrose," advancing north for nearly 1,200 feet. This will afford a channel 50 feet in width for 1,200 feet in length, and one 25 feet wide and 3,300 feet in length, with 20 feet depth of water at low-tide.

Seven thousand five hundred cubic yards of coarse gravel and sand have been removed from the southerly end of the bar adjacent to Gibson's wharf, making a cut 850 feet in length, 75 feet in width, with 18 feet depth of water at ordinary low-tide. The removal of rock from the channel near Locust-street wharf, which was in progress at the beginning of the fiscal year, has been completed; 19 feet depth of water is afforded at mean low-tide; the amount of rock removed from this locality during the year was 434 cubic yards. Considerable delay and interruption was experienced by the contractors during the progress of this work. They were inexperienced in that particular work, which, together with the unfavorable character of the material, required a much longer time to complete their contract than was originally anticipated. They have, however, completed their contract in accordance with the specifications, and satisfactorily. This improvement gives increased facilities to establishments largely interested in the importation and supply of Italian marble for the Philadelphia and other markets. In addition to the rock removed from the channel at Locust street, proposals were invited under date of June 21, 1873, for the removal of about 75 cubic yards of rock from the channel at and near South-street wharf. A contract was subsequently executed with the American Dredging Company of Philadelphia, who have during the fiscal year completed their contract, removing 172 cubic yards of rock, affording 16 feet depth of water at ordinary low-tide.

The removal of this amount of rock at this locality was requisite in order partially to relieve the entrance to the east draw-passage of the South-street bridge. Additional rock will have to be removed from this locality before the passage through the east draw of the bridge can be made available for large-class vessels.

During the present working-season it is proposed to continue the removal of the gravel-bar just above Penrose Ferry bridge, by excavating along the western and central portion of the same, up-stream from near

the bridge for a distance of 4,500 feet. This will remove about 70,000 cubic yards of material, and afford 20 feet depth of water at mean low-tide. It is proposed to continue the improvement of this river during the next fiscal year by increasing the width of the cut through the bar just above "Penrose" to 150 feet, and to remove fast and loose rock and coarse material from the channel opposite Gibson's wharf; also to increase the depth of excavation so as to afford 20 feet depth of water, and to a width of about 150 feet at ordinary low-water, up to this point.

The works for the improvement of the navigation of Schuylkill River are in the collection-district and port of Philadelphia. The nearest light-house is Fort Mifflin light; the nearest fort is Fort Mifflin.

Number of vessels registered at the port of Philadelphia, ——— ; tonnage of same, ———.

The amount of revenue collected at Philadelphia during the fiscal year ending June 30, 1874, was $8,264,699.53.

Abstracts of proposals and of contracts are transmitted herewith.

The estimate of 1870 for the improvement of the Schuylkill River accompanies this report.

Amount required to complete this work is $174,700.

Financial statement.

Balance in the Treasury of the United States July 1, 1873	$51,500 00
Amount in hands of officer and subject to his check	5,807 05
Amount appropriated by act approved June 23, 1874	20,000 00
Amount expended during the fiscal year ending June 30, 1874	54,975 12
Amount available July 1, 1874	20,000 00
Amount required for the fiscal year ending June 30, 1876	40,000 00

Abstract of proposals for removal of rock at South-street wharf, Schuylkill River, Pennsylvania, received and opened at 12 m. July 23, 1873.

No.	Bidder, name, and residence.	Rate per cubic yard.	Begin—	Complete—
1	The American Dredging Company, No. 10 South Delaware avenue, Philadelphia.	$25 50	Sept. 1, 1873	Dec. 1, 1873
2	Robert W. Warren, No. 7 Burling Slip, New York. (No guarantee.)	$45 00	Sept. 1, 1873	July 1, 1874

Abstract of contract for improving channel of Schuylkill River, Pennsylvania.

Contractor.	Removal of rock.	To commence—	To complete—
American Dredging Company, 10 South Delaware avenue, Philadelphia.	$25 50 per cubic yard	September 1, 1873	December 1, 1873

Estimate of 1870 for improving the Schuylkill River at its mouth, at Gibson's Point, and above to the Chestnut-street bridge.

Dredging at the mouth and at "Penrose"	$15,000
Dredging the river at Gibson's Point	10,000
The extension and widening of the cuts at Gibson's Point, to a depth of 18 feet at mean low-water of spring-tides, 35,000 cubic yards, at 50 cents	17,500
The extension of the 18-foot channel above Penrose Ferry bridge, through shoal spots, 18,000 cubic yards, at 40 cents	7,200
Deepening the cut at mouth of river, 10,000 cubic yards, at 30 cents	3,000
Dredging at Gibson's to afford 18 feet depth of water at mean low-tide, (rock)	13,000
Rock at Locust street	13,000

Widening and deepening the channel at the mouth to afford 20 feet depth of water at mean low-tide	$10,000
Widening and deepening the channel at Penrose Ferry bridge draw	3,000
To obtain 20 feet depth of water to Point Breeze wharves	27,000
To obtain 18 feet depth of water at mean low-tide to Chestnut-street bridge.	19,000
To obtain 20 feet depth of water at mean low-tide to Gibson's wharves	14,000
Removal of rock at Gibson's, 1,200 cubic yards, at $30	36,000
Removal of rock at Spruce street, 800 cubic yards, at $25	*20,000
Removal of rock at South street, 2,000 cubic yards, at $25	*50,000
	257,700
Total amount of appropriation	125,000
Total amount expended	105,000
Total amount required to complete the work	174,700
Total estimate of 1870	257,700
Increase in 1874	42,000
	299,700

V 6.

IMPROVEMENT OF DELAWARE RIVER AT FORT MIFFLIN BAR.

This improvement was authorized by act of March 3, 1873, appropriating $50,000 for commencing the work; and under contract with the Albany Dredging Company, dated June 25, 1873, work was commenced on the 15th July following, and has been prosecuted without serious interruption, except during the winter, to the present time. The extent of the bar, the seat of improvement, is about 1,500 feet by 800 feet, and during the fiscal year 140,000 cubic yards of material have been removed, the result of which thus far has been to open a channel through the bar along the eastern portion of the cut, affording twenty feet depth of water at mean low-tide, with a width of 300 feet. On the west, the same depth of water has been attained, with a width of 225 feet.

The locality of this improvement is about eight and a half miles down river from the United States navy-yard, in the direct course of all vessels arriving at and departing from Philadelphia. The Delaware River at this position is about one mile in width; the velocity of the current at half flood or ebb is about three miles per hour. In view of these circumstances, the rate at which this work is being carried on is very favorable for the United States.

The importance of this improvement is manifest in view of the establishment of new lines of steamships at Philadelphia, both foreign and coastwise, the increased commerce of the port, and a general healthy growth in mercantile pursuits. During the present working-season it is proposed to continue the dredging at the bar, and under the present contract, so as to afford 20 feet depth of water from the New Jersey channel on the south to the Pennsylvania channel on the north, with a width of 800 feet. This will require an additional removal of about 70,000 cubic yards of material, and will complete that part of the work now in process of execution.

By act of Congress approved June 23, 1874, $50,000 additional was appropriated for this improvement. With this amount it is proposed to increase the depth of water over the bar to 22 feet, with an average width of 1,200 feet, which will require a further removal of 173,000

*These items have been increased $42,000; the increase is in the price from $25 to $40 per cubic yard, not in the amount of material.

cubic yards of material. During the present season it is contemplated to remove 70,000 cubic yards of this amount, which will leave 103,000 cubic yards to be removed during the remainder of the fiscal year ending June 30, 1875.

For the next fiscal year it is proposed to continue the improvement of the river at this locality by increasing the general width of the excavation to 1,500 feet, with gentle side-slopes, and openings up and down stream of 2,000 feet in width, which will require the removal of 140,000 cubic yards more of material. This will require a further appropriation of $50,000.

The amount required for the entire completion of this improvement is $50,000. This work is in the collection-district of Philadelphia; the nearest light-house and fort are, respectively, Fort Mifflin light and Fort Mifflin.

The amount of revenue collected at Philadelphia for the fiscal year ending June 30, 1874, was $8,264,699.53.

Abstracts of proposals and of contracts accompany this report.

Financial Statement.

Balance in Treasury of United States July 1, 1873	$50,000 00
Amount appropriated by act approved June 23, 1874	50,000 00
Amount expended during the fiscal year ending June 30, 1874	27,189 03
Amount available July 1, 1874	66,981 62
Amount required for the fiscal year ending June 30, 1876	50,000 00

Abstract of proposals for improving Delaware River at Fort Mifflin Bar, received and opened at 12 m., Wednesday, June 11, 1873.

No.	Bidders' names and residences.	Dredging, per cubic yard.	To commence.	To complete.
1	Albany Dredging Company, Albany, N. Y	$0 21 90-100	July 1, 1873	June 30, 1874.
2	American Dredging Company, Philadelphia, Pa.	28	June 16, 1873	Dec. 31, 1873.
3	William H. Beard, Brooklyn, N. Y	23 5-8	July 10, 1873	July 1, 1874.

Abstract of contract made for the improvement of Delaware River at Fort Mifflin Bar.

Bidder's name and residence.	Nature of work, dredging.	Price per cubic yard.	To commence.	To complete.
Albany Dredging Combany, M. F. Brainard, treasurer, Albany, N. Y.	140,000 cubic yds., more or less.	$0 21 9-10	July 1, 1873	June 30, 1874.

V 7.

IMPROVEMENT OF DELAWARE RIVER AT HORSE-SHOE SHOALS.

It was recommended last year, in view of the expense of the proposed improvement, that it be deferred until it was found that, from further experience, ice-boats cannot keep the channel open at this point. The last winter having been very mild, no special experience on this point was obtained.

Financial statement.

Balance in Treasury of United States July 1, 1873	$49,500 00
Amount in hands of officer and subject to his check	154 80
Amount expended during the fiscal year ending June 30, 1874	154 80
Amount available July 1, 1874	49,500 00

V 8.

IMPROVEMENT OF DELAWARE RIVER BETWEEN TRENTON AND BORDENTOWN.

The work of improvement consists in dredging a channel of 6 feet depth, connecting the low-water 6-foot curves above and below Periwig Island Shoal. The dredging has progressed steadily during the working-season, interrupted somewhat by heavy freshets during the spring and fall. The channel has been carried through the shoal with a depth of 6 feet and a width of 75 feet, and is now being straightened and widened. Sixty thousand cubic yards of sand, gravel, and bowlders have been dredged during the year.

During the present working-season it is proposed to continue the work of widening and straightening the channel.

An appropriation of $25,000 is asked for the next fiscal year to continue the work of improvement at this point.

Trenton is in the collection-district of Burlington, Philadelphia being the nearest port of entry. The nearest light-house and fort are, respectively, Fort Mifflin Light and Fort Mifflin.

The revenue collected at Philadelphia during the year ending June 30, 1874, amounts to $8,264,699.53.

ORIGINAL ESTIMATED COST OF WORK.

To excavate a cut through the shoal at Periwig Island, 200 feet wide and 6 feet deep, will require the removal of 140,000 cubic yards of gravel, bowlders, &c., at 50 cents	$70,000 00
Below Newbold's Island, a cut 200 feet wide, 700 feet long, and 1 foot deep; 5,000 cubic yards, at 40 cents	2,000 00
Contingencies	3,000 00
Total	75,000 00

Total amount of appropriation	$35,000 00
Amount expended	10,150 55
Required to complete the work	40,000 00

Financial statement.

Balance in Treasury of United States July 1, 1873	$22,500 00
Amount in hands of officer and subject to his check	2,057 45
Amount appropriated by act approved June 23, 1874	10,000 00
Amount expended during the fiscal year ending June 30, 1874	9,708 00
Amount available July 1, 1874	14,949 27
Amount required for the fiscal year ending June 30, 1876	25,000 00

V 9.

IMPROVEMENT OF BROADKILN RIVER, DELAWARE.

The appropriation of $10,000 for the improvement of the Broadkiln River was applied in removing the shoals from Milton to Oyster Rock Shoals, near the mouth of the river.

A channel of 5 feet in depth at low-water, with a minimum width of 35 feet, has been made.

The appropriation having been exhausted, the work has been suspended, to be resumed should Congress make a further appropriation.

This work is in the collection-district of Wilmington, Del., which is the nearest port of entry; Fort Delaware is the nearest fort, and Delaware Breakwater Light the nearest light-house.

Abstracts of proposals and of contracts are sent herewith.

The accompanying report of Capt. M. R. Brown, Corps of Engineers, will give the details of this work.

The original estimated cost of this work was:

For making opening across beach to discharge waters of Broadkiln and Lewes Creeks into bay	$14,790
For dredging the Broadkiln River and building dam to turn the waters from Lewes Sound into New Inlet	65 657
Total cost of improvement	80,447

Amount appropriated since adoption of project	$10,000
Amount expended	10,000
Amount required to complete improvement	70,447

Financial statement.

Balance in Treasury of United States July 1, 1873	$10,000
Amount expended during the fiscal year ending June 30, 1874	10,000
Amount required for the fiscal year ending June 30, 1876	30,000

Report of Capt. M. R. Brown, Corps of Engineers.

UNITED STATES ENGINEER OFFICE,
Philadelphia, Pa., June 30, 1874.

SIR: Deferring to the wishes of those most interested in the improvement of the Broadkiln River, advertisements for proposals were delayed sufficiently long to admit of such inquiries and arrangements on the part of business men desiring the improvement that a company formed of themselves might be able to bid for the work and invest the profits in further improvements of the stream.

The advertisements were dated June 21, and the bids were opened July 23, 1873.

The American Dredging Company made the lowest bid, viz, 30 cents per cubic yard. The contract was accordingly awarded to them. It was signed on the 14th of August, 1873.

Further progress was delayed by accidents to the contracting company's dredges until November 8, 1873, when one dredge began excavating.

It was found that the strictest construction of the terms had not been the interpretation accepted by the dredging company; and in order to avoid the use of tub-scows the company finally agreed to count only one-half of the buckets thereafter dredged, provided they should be allowed to dump the contents of the dredges above low-water mark, which they could accomplish directly from the dredges instead of placing the material in the rear of the banks, the latter method requiring the use of tub-scows and a derrick-scow. This arrangement was greatly for the advantage of navigation, and was gladly agreed to by all parties concerned.

The work continued until April 3, 1874, sometimes with one dredge and often with two.

By this time the money was exhausted. The entire river had been so dredged out as to provide a practicable channel 5 feet in depth throughout its course; all that was deemed desirable.

Twenty-seven thousand two hundred and seventy-four cubic yards of material have been excavated from the river and *paid for*, while nearly the same amount additional has been taken from the bed without cost. No further appropriation has been made.

It is proposed at some future time, if Congress grants the money, to cut a channel through the peninsula, Lewes Point, at the most practicable locality, nearly simultaneously damming up the old passage into Lewes Sound.

It is believed that navigation in both the Lewes and Broadkiln Rivers would be greatly benefited by this improvement, and that the long delays of vessels desiring to pass from the Broadkiln and Lewes Rivers into the Delaware Bay, now so frequent, would be mostly obviated. Thirty thousand dollars would be needed to accomplish this work.

Very respectfully, your obedient servant,

M. R. BROWN,
Captain of Engineers, U. S. A.

Lieut. Col. J. D. KURTZ,
Corps of Engineers.

Abstract of proposals for improvement of Broadkiln River, Delaware, received and opened at 1 p. m. July 23, 1873.

No.	Bidders' names and residences.	Dredging, per cubic yard.	Time of commencement.	Time of completion.
1	G. H. Ferris, Brooklyn, N. Y.	$0 45	Oct. 1, 1873....	July 1, 1874.
2	American Dredging Company, Philadelphia, Pa	30	Oct. 1, 1873....	Dec. 31, 1873.
3	Broadkiln Improvement Navigation Company .	35	Sept. 1, 1873...	July 23, 1874.

Abstract of contract for improvement of Broadkiln River, Delaware.

Contractor.	Dredging.	To commence.	To complete.
American Dredging Company, 10 South Delaware avenue, Philadelphia.	30 cents per cubic yard.	Oct. 1, 1873....	Dec. 31, 1873.

V 10.

IMPROVEMENT OF SOUTH RIVER, NEW JERSEY.

Under the appropriation of $5,000, made March 3, 1873, dredging was done at such spots, in the canal joining the South and Raritan Rivers, as had shoaled by the undermining of the banks and deposits from the river. On completion of the work, a channel of 6 feet in depth existed throughout the canal.

South River is in the collection-district of Amboy; fort at Sandy Hook is the nearest fort; and the nearest light-house that at Prince's Bay.

Financial statement.

Balance in Treasury of United States July 1, 1873.....	$5,000
Amount expended during the fiscal year ending June 30, 1874.....	5,000

V 11.

IMPROVEMENT OF THE NORTH AND SOUTH BRANCHES OF THE SHREWSBURY RIVER, NEW JERSEY.

The appropriation of $5,000, made for this place, was expended in removing the bulk-head of sand that had formed at the north end of the Rocky Point channel, and at other points where shoaling had occurred.

Shrewsbury River is in the collection-district of Amboy; fort at Sandy Hook is the nearest fort; and the Navesink light is the nearest light-house.

Financial statement.

Balance in Treasury of United States July 1, 1873.....	$5,000
Amount expended during the fiscal year ending June 30, 1874.....	5,000

V 12.

IMPROVEMENT OF COHANSEY CREEK, NEW JERSEY.

The work of improving the navigation of this creek was commenced in July, 1873, by the American Dredging Company, and was closed in

December of that year, 24,139 cubic yards of sand and mud having been removed from the bed of the creek.

A channel of 75 to 80 feet in width, and 3 feet depth at low-water, was opened along the wharves of the city of Bridgeton, and for a distance of half a mile below Broad-street bridge, to deeper water.

No appropriation has been made for the year ending June 30, 1875.

To widen the channel below Broad-street bridge to 130 feet, with a depth of 3 feet at low-water, will require an additional appropriation of.....	$10,000 00
To widen it to 130 feet, and at the same time increase the depth below Broad street to 4 feet at low-water, will require in addition	10,000 00
Amount required to complete the work.....	20,000 00

Amount expended during the year.

Dredging 24,139 cubic yards, at 36 cents	$8,690 04
Contingencies	1,309 96
Total	10,000 00

Cohansey Creek is in the collection-district of Bridgeton, N. J., which is the nearest port of entry.

Cohansey light is the nearest light-house, and Fort Delaware the nearest fort.

Abstracts of proposals and of contracts accompany this report.

Financial statement.

Balance in Treasury of United States July 1, 1873.....	$10,000
Amount expended during the fiscal year ending June 30, 1874.....	10,000
Amount required for the fiscal year ending June 30, 1876	20,000

Abstract of proposals for improvement of Cohansey Creek, New Jersey, opened at 1 o'clock p. m. Thursday, May 29, 1873.

No.	Bidders' names and residences.	Character of work—dredging mud, sand, and gravel.
1	G. H. Ferris, Brooklyn, N. Y	47½ cents per cubic yard if deposited in deep water; 75 cents per cubic yard if used for filling in wharves.
2	The American Dredging Company, Philadelphia.	36 cents per cubic yard if measured in scows; 22 cents per cubic yard, measured in buckets, if deposited directly from the dredge.

Abstract of contract made for improvement of Cohansey Creek, New Jersey.

Contrator's name and residence.	Nature of work, (dredging.)	Price per cubic yard.	To commence—	To complete—
The American Dredging Company, Philadelphia.	25,000 cubic yards, more or less.	36 cents if deposited from scows; 22 cents if deposited from dredge.	July 15, 1873	Dec. 1, 1873.

V 13.

PORT-WARDEN'S LINE, PHILADELPHIA.

In accordance with the instructions from your Office of June 23, 1873, that portion of the report of the Board of Engineers of March 24, 1873, referring to the above subject, was sent to the mayor of Philadelphia,

and by him laid before councils for their consideration, since which nothing has been received by me respecting the matter.

A copy of my letter to the mayor is inclosed herewith:

UNITED STATES ENGINEER OFFICE,
Philadelphia, Pa., July 11, 1873.

SIR: I have the honor to transmit to you herewith, in execution of the instructions of the Chief of Engineers to me, of which a copy is also inclosed, a copy of so much of the report of the Board of Engineer Officers of March 24, 1873, as relates to the harbor-lines of Philadelphia; and I request that the subject may be brought by you to the consideration of the councils of the city, as contemplated by the same instructions.

I shall be ready to take such further steps in the matter as may be found necessary and expedient.

Very respectfully,

J. D. KURTZ,
Lieut.-Col. of Engineers.

Hon. WM. L. STOKLEY,
Mayor of Philadelphia.

V 14.

BREAKWATER, CROW SHOALS, DELAWARE BAY.

UNITED STATES ENGINEER OFFICE,
Philadelphia, Pa., February 14, 1874.

GENERAL: I have the honor to present the following report respecting harbor of refuge under Crow Shoal, New Jersey. This subject was placed in my charge by your instructions of March 15, 1873, and is provided for in the law of March 3, 1873, "making appropriations for the repair, preservation, and completion of certain public works on rivers and harbors." (General Nature, No. 61.)

"Section 2. For surveys and examinations * * * at Crow Shoals, Delaware Bay, near Cape May light, New Jersey, for an artificial harbor or breakwater."

The field-work of the survey was executed in August, 1873, by a party under the direction of Mr. F. M. Eppley. The area to be examined has a superficies of about twenty-three square miles, embracing the shoal and roadstead covered by it, and the channels of approach and exit. Being in an open sea, the best that could be done with the funds that could be made available for the purpose was to make a general hydrographic reconnoissance and run in the connected shore-line. The work was greatly facilitated by the aid of a steam-tender belonging to the Light-House Establishment, the use of which was kindly allowed during the operations. A comparison of the results with the survey made in 1836 by Major Hartman Bache, Corps of Topographical Engineers, and with the hydrographic sheets of the Coast Survey for 1842-'47, affords the means of judging somewhat of the changes that are in progress in the locality, of the value of the roadstead for shelter, and of the probable stability of the channel-ways connected with it.

The report of Mr. Eppley, with his plat of the survey, and a sheet giving a comparison of it with surveys of 1836 and 1842-'47, accompany this report, the drawings going by express.

Cape May or Crow Shoal roadstead is a magnificent natural anchorage, having a depth of 24 feet at low-water, through an area of about three miles superficial. It is well covered by the shoal lying on its western (bay) side, and the ocean-waves are excluded or broken by the shoals at its entrance. The cause which interferes with its general use by vessels is the difficulty attending access to it through the comparatively narrow channels connecting it with the ocean. The Cape

May channel affords 24 to 30 feet of water, but its width is sharply trenched upon by shoals upon both hands, notably by the shoals lying just south of the light-house. A breakwater of moderate profile placed along Crow Shoal will afford whatever addition is needed to the protective power of the shoal itself, but the entrance to the roadstead requires to be regulated by the removal of the projecting shoal, and of the other obstacles that hinder its navigation.

The comparative chart shows that the shoal now lying off the light-house, to the southward, distant about a thousand yards from the shore, has moved eastward four or five hundred yards since 1842–'47, and that the slough which was then forming between it and the shore has developed into an 18-foot channel, which now separates the shoal from the beach. This is an extraordinary movement for this shoal, the shape and position of which indicate hardness and persistence of composition.

Any project for converting the roadstead into a smooth harbor should include protective works against the ice which must be driven into the anchorage, from the bay and from Maurice River Cove, by northwardly and northwesterly winds. Several years' observations at Lewes show that there is also liability to the formation of ice on the surface of the harbor itself, and that this ice is just as formidable a trouble as that which drifts in or is blown in from the general bay. A number of winters may pass without giving any trouble from ice, and yet its entrance requires to be guarded against with suitable structures, which after all exert no preventive power against its formation within the harbor.

The peculiar advantage of the existing harbor of refuge near Cape Henlopen is the broad and free approach to it which vessels enjoy at all times. Its area is trivial compared with that of the Cape May roadstead, and it is undergoing deterioration, due probably to the works themselves. It is too small to afford room for the large numbers of vessels resorting to it for shelter, and the need is great for additional room for this purpose. The commission of experienced officers who projected this harbor in 1828 could not forecast the development of the great maritime empire for which they were providing, and their work is consequently entirely inadequate to the present and future wants of the country. The commerce of the Delaware and of the Atlantic seaboard has outstripped all probable growth, and needs greatly increased accommodation.

The subject is presented and discussed by Major Bache in the report of December, 1837, accompanying his survey of 1836, cited above.

Examination of the comparative chart shows general favorable conditions for the construction of a breakwater on Crow Shoal, and the use of the channels connected with the roadstead. Cape May and Ricord's Channels have deepened materially, and may, therefore, be used by larger vessels than formerly. The northern half of Crow Shoal has, however, been materially washed, and there appears to be a corresponding shoaling of the inner part of the roadstead, which still remains, however, of liberal dimensions, both of area and depth. A stone barrier placed along the shoal would arrest the tendency to wash away, and probably check the deposits in the deep water. A general wearing of the shore-line seems to be in progress.

On the whole, I consider the works necessary to establish a harbor of refuge at Crow Shoal roadstead to be as follows:

1. A solid breakwater along the shoal.
2. Opening the channel of approach by dredging.
3. Ice-piers across the upper end of the harbor.

The small sketch on the comparative chart exhibits this project, and an estimate of the probable cost accompanies this report.

The examination of this subject necessarily brings up the general question of harbors of refuge at the mouth of Delaware Bay. The great importance of provision for this purpose was insisted on many years ago, and the result was the formation of the existing harbor under Cape Henlopen. In later years the question has been how to provide the additional harbor-space which the growing commerce of the Atlantic seaboard requires. This question has been treated by the several officers who preceded me in the charge of the work, and has been considered to require the enlargement of the existing harbor by some one or other method. This is the natural and obvious conclusion, in which I have acquiesced. But I have become more and more impressed with the conviction that the harbor itself is a mistake—one that could not be avoided in the circumstances under which it was projected, but which is now apparent in the greatly changed condition of the country. The closing paragraph of Mr. Eppley's report is of great weight in this respect.

I feel confident that the deep water pocket on the Delaware side covered by the "Shears" is the locality that must eventually become the harbor of refuge for the mouth of the Delaware, unless the entrance to Crow Shoal roadstead can be made of ample width and easy access, and so maintained. This is so important a matter that it cannot be discussed at the close of this report. It is merely suggested as having a bearing upon any examination of the subject of increase of harbor-space at the mouth of the Delaware. It is believed that the granite masses now forming the breakwater and ice-breaker of the Delaware Breakwater harbor can be removed and replaced along the southwestern edge of the "Shears" Shoal at a cost that would not be inordinate in view of the vast advantage that would result from the change.

Very respectfully, your obedient servant,

J. D. KURTZ,
Lieut. Colonel of Engineers.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

Report of Mr. F. M. Eppley, Assistant Engineer.

UNITED STATES ENGINEER OFFICE,
Philadelphia, January 8, 1874.

SIR: I beg leave to submit for your consideration the following report upon the hydrographic survey of Crow Shoal, Delaware Bay, including the roadstead lying between Crow Shoal and Cape May County, New Jersey, and adjoining shoals and channels.

The object of the survey is to ascertain the expediency of constructing a breakwater or artificial harbor on or at Crow Shoal, to afford shelter to vessels during storms or unfavorable weather.

A chart of the survey, drawn to a scale of $\frac{1}{10000}$, accompanies this report, upon which the contours are shown from one to four fathoms, mean low-water. The data used in constructing the chart are as follows: A measured base-line 4141.6′; eight trigonometrical stations, at which 94 angles were taken; one hundred and forty miles of sounding lines; 5,285 soundings; 1,146 hydrographic angles; four miles shore-line or topography; twenty-eight observed high and low tides; and a hasty examination of the direction of currents in the roadstead. The whole work covers an area of 29 square miles, and was completed in 16 working-days.

The hydrometric data is not as satisfactory as desired, owing to our short stay at Cape May. A tide-gauge was erected at the wharf or "People's Landing," and observations were carefully taken every 15 minutes by an intelligent observer, and the records were examined at intervals by my assistant, Mr. Howard Kennedy, and myself. A full lunation, or 57 consecutive tides, are necessary for the construction of a complete

tide-table. Even then there are certain anomalies which can only be eliminated by long and careful observations. The summer tides are larger than those of winter. This is caused entirely by winds. The southerly or summer winds carry the water into Delaware Bay, and a full tide is the result, while during the winter months the northwest winds prevail, driving the waters out of the bay, producing low tides.

The following comparative table will show the difference between the present observations and the standard observations of the Coast Survey:

	U. S. Engrs.	U. S C. S.	Difference.
Mean rise and fall	5 ft. 1 tenth..	4 ft. 2 tenths.	Of 9 tenths..
Mean duration of rise	6 hrs	6 hrs. 25 m...	25 m
Mean duration of fall.	5 hrs. 36 m...	6 hrs. 0 m....	34 m
Mean stand of high-water	0 hrs. 24 m...		
Mean stand of low-water	24 m		
Mean low-water or plane of reference, (reading on tide-gauge)	5 ft. 9 tenths.		
Highest observed tide, (wind S. E.)	6 ft.		

From the foregoing the difference is manifest, as already explained. A common staff, marked to feet and tenths, was used in making our observations, and is not considered as accurate as the box-gauge in exposed situations or in localities where heavy ground-swells prevail, as at Cape May.

Regarding the force and direction of winds as very essential in the discussion of this work, I insert the following official tabular statement of mean direction and force of winds and other meteorological data, for which I am indebted to Mr. T. F. Townsend, observer Signal-Service, U. S. A., at Cape May City:

Official tabular statement of mean direction and force of winds, and other meteorological data, at Cape May City.

[Computed from the following hours of observation: 7 a. m., 7.43 a. m., 2 p. m., 4.43 p. m., 9 p. m., 11.08 p. m., local time. Barometer corrected for temperature and elevation.]

Date.	Barometer.			Thermometer.			Wind.			Rain.	
	Mean.	Highest.	Lowest.	Mean.	Higheat.	Lowest.	Prevailing direction.	Maximum velocity during month.	Total number of miles.	Amount in inches.	Number of days on which rain or snow fell.
June, 1871	29.960	30.240	29.540	67.0	84	59	S.	260	4,985	3.68	10
July, 1871	29.975	30.230	29.560	72.0	87	61	W.	360	4,845	5.02	7
August, 1871	30.020	30.320	29.610	74.0	84	62	S.	425	5,195	2.50	9
September, 1871	30.120	30.420	29.760	64.0	78	42	N. W.	395	5,670	2.72	3
October, 1871	30.150	30.560	29.700	58.7	74	39	S.	585	7,345	4.91	7
November, 1871	30.049	30.510	29.370	43.0	54	26	N. W.	790	9,115	6.42	7
December, 1871	30.120	30.600	29.570	30.6	48	4	N. W.	760	8,825	2.90	8
January, 1872	30.080	30.480	29.630	31.5	48	11	N. W.	660	9,270	2.99	12
February, 1872	30.010	30.630	29.400	31.7	50	12	N. W.	620	8,735	2.99	11
March, 1872	30.033	30.500	29.440	32.6	54	7	N. W.	650	10,726	6.61	16
April, 1872	30.070	30.440	29.520	48.0	73	34	S.	600	9,005	.92	8
May, 1872	29.985	30.300	29.500	59.1	77	46	S.	520	8,860	2.23	8
June, 1872	30.000	30.270	29.570	66.8	84	53	S.	535	6,555	2.15	10
July, 1872	29.980	30.230	29.720	75.1	92	67	S.	275	5,560	3.27	8
August, 1872	30.047	30.270	29.678	73.1	81	60	S.	505	4,935	3.09	7
September, 1872	30.046	30.270	29.766	67.4	77	53	N. W.	475	6,335	4.51	8
October, 1872	30.098	30.530	29.650	56.2	72	39	N. W.	500	8,596	3.28	9
November, 1872	30.101	30.590	29.607	43.0	56	19	N. W.	650	8,485	2.71	10
December, 1872	30.167	30.560	29.496	31.4	49	10	N. W.	590	9,365	2.65	13
January, 1873	30.087	30.481	29.597	32.7	47	6	N. W.	455	7,510	5.57	14
February, 1873	30.014	30.588	29.247	32.2	48	5	N. W.	755	.....	7.61	11
March, 1873	30.006	30.740	29.200	37.0	57	9	N. W.	770	10.695	3.07	9
April, 1873	29.943	30.261	29.653	46.8	59	40	S. & E.	580	8,225	3.95	14
May, 1873	30.007	30.441	29.481	55.9	73	44	S. & E.	480	7,280	3.29	9

A survey of Crow Shoal was made in 1836 by Major Hartman Bache, United States Topographical Engineers, for a similar purpose, but as it did not receive an appropriation from Congress, was consequently abandoned for a time. The following resolutions will fully set forth the advantages that are claimed to follow the construction of an artificial harbor at Crow Shoal:

Extract from the journal of the seventeenth Senate of the State of New Jersey, 1861, (*p.* 434.)

* * * * * * *

"It is well known that for over twenty years the question of the construction of an artificial harbor on Crow Shoal, on the north side of Cape May, has been contemplated.

"The breakwater at Cape Henlopen, fourteen miles southerly from Cape May, designed for ships and large-class vessels, is not sufficient to accommodate even that class.

"Not unfrequently is it the case that so great is the number of large-class vessels that no protection can be afforded to small vessels. Indeed, they would regard themselves more secure from danger at sea than in such a harbor under such circumstances.

"Your committee, though desiring to be brief, cannot omit calling attention to the great increase in the coasting-trade. This increase is owing to the very great and increasing demand for coal at the East.

"Were there no other reasons why this breakwater should be made, this would be a sufficient argument in favor of its construction; but, in addition to this, large amounts of grain and merchandise naturally pass through the Cape May Channel.

"The amount of enrolled tonnage of the State of New Jersey (and a large portion of New Jersey tonnage is enrolled in the districts of New York and Philadelphia) now reaches about 150,000 tons.

"A large proportion of this would be greatly benefited by this contemplated harbor.

"The estimated value of merchandise carried annually by the line of the New York Steam Navigation Company is $20,000,000.

"The recent meeting of citizens from the West, at Philadelphia, and the result of that meeting, is likely to make the city of Philadelphia an immense grain market, which, it may be added, is an additional argument."

* * * * * * *

Number of vessels freighting coal from Port Richmond to Philadelphia in 1859	3,255
Tons of coal freighted	806,445
Number of men employed in the vessels alone	19,350
Amount of capital invested in vessels	$64,500,000

Much may be added to this, so that the estimates may be regarded as falling greatly short of a true statement. The importance, then, of this contemplated harbor cannot be overestimated.

As before stated, the location agreed upon by our most experienced nautical and scientific men as the only practicable place to afford the requisite facilities for protection to the worthy and numerous class of men engaged in this useful and necessary trade, and to the large amount of invested capital, is Crow Shoal, Cape May.

* * * * * * *

Joint resolutions in relation to the construction of an artificial harbor on Crow Shoal, Cape May, for the protection of small-class vessels.

Whereas the construction of a breakwater or artificial harbor in Crow Shoal, Cape May, for the purpose of affording protection, especially in stress of weather, to that portion of commerce known as the coasting-trade, and to all small-class vessels, has long been in contemplation; and

Whereas the great increase of this branch of domestic commerce has so increased the demand for improvement, that has always been deemed as important, has become an absolute necessity, without which all small-class vessels must continue to be exposed to danger of the ocean, which might be avoided; and

Whereas many of the States are equally interested with ourselves, but not having their attention properly called to the subject, and not being altogether aware of the benefits to be derived from the proposed harbor, have not had the feelings of their citizens fully enlisted in the subject; and

Whereas it is the interest of New Jersey to adopt immediately some practical measures by which States interested in the subject may become enlisted and aid from the Federal Government be obtained: Therefore,

1. *Be it resolved, (house of assembly concurring,)* That the governor of this State be, and is hereby, authorized to appoint, at his discretion, a committee of three, whose

business and duty shall be to visit the different States interested in this subject and solicit, through the governors and legislatures of said States in Congress, and urge the passage of an act making an appropriation for said artificial harbor.

2. *Be it resolved*, That the governor be, and he is hereby, authorized to draw on the treasury for an amount not exceeding fifteen hundred dollars, out of any money not heretofore appropriated, to be paid to said committee for the purpose of aiding in defraying their reasonable and necessary expenses.

DOWNS EDMUNDS.
NATHANIEL S. STRATTON.
DAVID D. SCHIMP.
J. E. SMITH.
JONATHAN F. LEAMING.
SAMUEL POPE.
C. E. P. MAYHEW.

RESOLUTION OF DELAWARE-BAY PILOTS

We, a meeting of the Delaware pilots, held Thursday, August 21, 1873, *at Cape May City, do recommend the advantage of a breakwater on Crow Shoal.*

1st. All easterly-bound coasting-vessels are compelled, during the prevalence of all thick, easterly weather, to shelter within the capes. Immediately following which the wind suddenly veering to the northwest during the night, not affording sufficient time to weigh anchor and get to sea, are subjected to shipwreck and loss of life.

2d. That vessels seeking harbor off Cape May, and somewhat northerly also, may hold the windward shore and run into a breakwater on Crow Shoal; whereas to cross the Delaware would be exceedingly hazardous.

3d. A breakwater on Crow Shoal would afford a secure harbor within a shorter distance of over thirteen miles than the one at Cape Henlopen.

4th. A harbor properly constructed on Crow Shoal will be the best and most secure harbor against the ice in Delaware Bay, which now is or may be hereafter constructed.

5th. We are also of the opinion that not less than four-fifths of all the vessels trading in and out of Delaware Bay can easily approach this harbor, so far as the depth of water is concerned.

6th. This harbor would be a great advantage to steamers now landing thousands of passengers annually within the capes *en route* for Cape May City, whose lives and property are more or less endangered at the present time without the protection which the breakwater would afford.

7th. The present breakwater at Henlopen does not afford sufficient anchorage accommodations for coasting-vessels passing in and out by Cape May.

WILLIAM BENNETT,
JOHN STEVENS,
ISRAEL HUGHES,
HORATIO H. CHURCH,
N. B. SMITH,
THOMAS ELDRIDGE,
THOMAS B. SCHELLENGER,
WILLIAM F. HAND,
Branch Pilots.

Crow Shoal lies west of Cape May County; runs about north and south, nearly parallel to the shore. It is supposed to have been an island at one time, and now seems to be a part of Maurice River Flats. It has from 6.5 feet to 12 feet of water over it at mean low-water. In extent it is two miles long, one-quarter mile wide, tapering at both ends. It feels hard to the lead when sounding. No borings were made for specimens of substrata, but from such observations made for that purpose upon other shoals in Delaware Bay, I am led to believe that it is composed of fine sand and mud to a depth of 10 feet, when gravel and clay would be reached. The geological formations of Cape May County are two, viz, drift and alluvion, and belong to the Quarternary system. Few bowlders are found in this county, and none in the immediate vicinity of the proposed work. Quartz pebbles are very abundant.

In order to give an approximate idea of the stratum found in this locality, I append the following memorandum of the different kinds of earth passed through in digging a well at Congress Hall, Cape May City, two miles from Crow Shoal. It may not have any particular bearing upon this work, but may prove valuable in the future: One foot soil; 4 feet hard, pebbly gravel; 10 feet coarse sand; 4 feet clay; 2 feet clay, with crusts of iron; 9 feet white sand with an abundant supply of water; whole depth, 30 feet. From a reliable source I learn that Cape May is rapidly cutting away. The shore in front of Cape May City has suffered much from encroachments of the sea; nearly one mile has washed away since the Revolution. At Town Bank, the immediate

site of the contemplated harbor, there has been a rapid wear of the shore. Nathan C. Price, a surveyor of Town Bank, says his lines which ran to the shore are shorter by 50 rods than they were in 1776. A range of sand-hills, commencing about west by south from the light-house, and running about north in the direction of Higbee Signal, can easily be traced by the eye, and evidently marks the original line of the shore many years ago. The area inclosed by the sand-hills and present shore-line gives life to varied vegetable matter, much of which is foreign to this immediate locality, which clearly demonstrates an alluvial formation of a comparatively recent period. Hence, from the foregoing, the shifting tendency of this locality is clearly shown, and should be well considered in the study of this project.

There are two channels used in carrying on the commerce of Delaware Bay. The main ship-channel has an almost unlimited depth of water through the bay, commencing nearly abreast of Cape Henlopen, and runs about northwest. The Cape May Channel runs nearly east and west to the red buoy, or where the light-house bears north, where its course is changed to northwest, to connect with Ricord's Channel.

The tracks of inward-bound vessels are marked in broken lines upon the chart. There are about 24 feet of water in the Cape May Channel, while Ricord's Channel has 20 feet, a gain of 4 feet in depth since the Coast Survey chart was made.

The main channel is used by all large-class vessels. Cape May and Ricord's Channels afford a good entrance for vessels of light draught and some large coasters bound in "light."

"Statement of vessels observed by the light-house keeper at Cape May, N. J., during the years stated below, passing in or out of Delaware Bay by the channels on the New Jersey side.

Years.	Barks.	Brigs.	Schooners.	Sloops.	Steamers.	Total.	Remarks.
1866	.....	.....	6,187	963	140	7,290	Transcript of daily register from 1866 to 1872.
1867	1	1	5,155	755	128	6,040	
1868	.....	3	5,843	688	220	6,745	
1869	3	13	7,024	1,344	408	8,792	
1870	.....	.....	8,186	2,069	704	10,959	
1871	.....	.....	9,985	1,826	873	12,684	
1872	.....	.....	9,472	1,254	892	11,618	

"The journal of vessels passing in vicinity of light is not headed for pilot-boats, consequently they are numbered with the schooners. There are a number of vessels that pass this cape in the night that we don't see. But few vessels pass this cape late in the fall and during the winter months, from the fact of there being no harbor for safe anchorage short of Morris River, twenty miles above the cape. Coal-vessels bound north, that would prefer running the Jersey channel, go down the Delaware side and anchor in the breakwater, where they can lie with safety until wind and weather are favorable for going to sea. Pilot-boats, for the same reason, seldom anchor on this side except in the summer months.

"D. E. FOSTER,
"Keeper Cape May Light."

The harbor-master of Philadelphia informs me that there are about 500 coasting-vessels trading with the port of Philadelphia, through the Delaware Bay, making from 7 to 8 annual trips. The average draught of these vessels is from 11 feet to 13 feet.

The following is a list of wrecks taken from the official journal of the light-house-keeper at Cape May:

"Schooner Joseph Maxwell came ashore on the main beach about 4½ o'clock on the morning of September 25, 1868, in a fog; bound to Philadelphia from Bath, Me.

"2. Schooner William Wallace came ashore on Cox's Shoal near Cold Spring Inlet, about 6 miles east of Cape May light, on Sunday night, October 6, 1872. She had evidently been run into, there being a large hole in her side, and her masts were cut away; supposed to have been run down by a steamer, near the light-ship on Five Fathom Bank; wind on Saturday southeast, gentle.

"3. On the night of 25th October, 1872, about 8 o'clock, wind east, blowing half gale, an Australian brig from Rio Janeiro, bound to New York, came ashore on the main beach, about three miles east of Cape May light.

"4. On Sunday night, October 20, 1872, a schooner struck on a shoal up the Delaware Bay, about 10 miles above Cape May light.

"5. November 25, 1872, schooner from Somerset, Mass., bound to Philadelphia, was working into Delaware Bay, with fresh southwest breeze; attempting to go about, 'missed stays' and came ashore on the beach about three miles east of Cape May light.

"March 29, 1873, schooner Clara Davidson came ashore on Cold Spring Bar, six miles east of Cape May light. She was from North Carolina, bound to Philadelphia; wind northwest, blowing heavily, rough sea."

The following was taken from one of the Philadelphia journals since my departure from Cape May:

"October 29, 1873. The schooner Annie Magee, from Boston to Philadelphia, parted chains and came ashore on the beach near the steamboat landing, during a heavy gale from N. W. N. Vessel will be gotten off."

The above mentioned is the only vessel that has come to my knowledge as having sustained injury when harboring in Cape May Roads. By reference to the foregoing extracts from the light-keeper's journal at Cape May it will be seen that nearly all the wrecks occurred several miles to the eastward of Cape May, and I have no doubt that the want of a small light or beacon at Hereford or Cold Spring Inlet was the cause of many of these disasters. A light at Hereford Inlet is now in course of construction.

The work of constructing a harbor at Crow Shoal for the better protection of coasting vessels would involve a breakwater of not less than one mile in extent, situated directly inside the 12-foot curve on the east side of Crow Shoal, thereby protecting a part of the "pocket" or cul de sac known as Cape May Roads from the violence of the sea generated by westerly winds and from floating ice during the winter months. The favorable trend of the shore and the configuration of the bottom of this locality exhibit many points in favor of the construction of such a work, and may be regarded in almost every respect feasible, if not expedient.

Such a work would only be found useful during the winter months in protecting vessels from northwest winds, but, with the wind from that direction, it would be impossible for vessels to get into the harbor; besides, at such times there is good anchoring ground under the lee of the main beach, on the east side of the cape. I have been informed by pilots and others that they have seen from fifty to sixty vessels anchored at that place during northwest gales without sustaining loss or injury. I do not think that the existence of a harbor at Crow Shoal would induce more vessels to use the Cape May Channel, as the average draught of vessels in the coasting-trade is too great to navigate with safety in this locality. Pilots seldom bring vessels through this channel which draw more than 10 feet of water.

During the summer months, when southerly and easterly winds prevail, the Cape May Channel affords a good entrance to vessels of light draught and large "coasters" bound in "light," especially those from the eastward. They almost invariably have a fair wind at such times, which permits them to pass through Cape May and Ricord's Channels into Delaware Bay. Under such circumstances a harbor at Crow Shoal is not required. During the winter months, when the northwest winds prevail, we have not this advantage. These channels become somewhat dangerous, as it compels the mariner to beat against head-winds through a comparatively narrow channel, thus greatly endangering his vessel by running aground on the contiguous shoals should the vessel "miss stays" in "going about." In fact, it would be impossible to navigate this channel during head-wind and tide, to say nothing of the floating ice, which, influenced by the northwest winds, must necessarily encumber these channels entering the Delaware Bay by the lee shore. This fact alone would almost preclude any attempt to construct a harbor or ice-breakers upon a lee shore.

Cape May Roads is now sufficiently protected to insure safety to all ordinary vessels against any sea that may be propagated in Delaware Bay. By reference to the chart it will be seen that Crow Shoal is hard, while immediately inside we have a soft, sticky bottom. It is a well-established fact that soft mud cannot repose near the surface in exposed situations, and its presence in comparatively shoal water in this case seems to be a delicate test of the depth to which the disturbance at the surface has reached, and may be regarded as an evidence of its protection against heavy seas. A heavy sea approaching the roadstead from any direction of exposure cannot reach it without first encountering shoal water, which tends to break off the violence of the sea. Mr. D. Stevenson says, to the production of considerable undulations capable of injuring marine works or endangering their stability, these conditions are necessary:

1st. "That the sheet of water acted upon shall have considerable area.

2d. "That its configuration shall be such that the wind moving over it in any direction shall act upon its surface extensively, both in direction of length and breadth.

3d. "That the depth of water shall be considerable and unobstructed by shoals, so as to permit undulations to develop themselves to a great extent without being checked by retardations caused by shallow water and unequal bottom."

A glance at the Coast-Survey chart of Delaware Bay will show the greatest length of "fetch" or area of water over which the wind can act to be 50 miles in the direction of N. W. It will also be seen that the undulations propagated by these winds must pass over considerable area of shoal water, and before reaching the roadstead a greater obstacle presents itself in the existence of Crow Shoal. If, during storms, these waves be of an oscillatory character, they become breakers or waves of translation upon reach-

ing Crow Shoal. The effect of this would be comparatively smooth water in the roadstead. Even in the absence of all the advantages derived from the shoals, the sea could not be great, owing to the short distance of the "fetch."

In discussiug this subject I have only considered the northwest winds, as they are conceded to be the only winds capable of producing seas which would endanger the safety of vessels.

With the present improvements in ship-building, and the increased size of ground-tackle which vessels now carry, it would seem fair to suppose that vessels could anchor anywhere in Delaware Bay in the absence of floating ice. Our blockading squadron during the late war lay at anchor in the open sea along the Atlantic coast, subject to the fury of waves of 10 feet to 20 feet high, and were seldom known to get under way on account of storms.

I have not been able to learn upon inquiry from many naval officers that any of these vessels were lost. This case may only apply to large vessels, but in dealing with this subject we must regard the coasting-vessels much increased in size when compared with those of fifteen years ago. At that time schooners carrying from 150 to 200 tons were considered very large, and it would have seemed absurd to put "fore-and-aft" sails upon vessels of a larger size, while at present there are comparatively few vessels in the coasting-trade of less than 200 tons, and the majority carry 500 tons and upward.

The pilots of Delaware Bay are almost unanimous in recommending a breakwater on a shoal known as the "Shears," on the west side of the main ship-channel. This site is nearer the deep water, and would be available for all classes of vessels, while the harbor at the Delaware Breakwater in a few years will only afford protection to small vessels, as it is filling up very fast. Should the harbor at Crow Shoal be made, we will then have no protection for large vessels, and a harbor on each side of Delaware Bay for small ones.

Very respectfully, your obedient servant,

F. M. EPPLEY.

Lieut.-Col. JOHN D. KURTZ,
Corps of Engineers, U. S. A.

Estimate of probable cost of a harbor of refuge at Crow Shoal Roadstead, New Jersey.

2,204,000 tons granite, at $3.50 per ton	$7,714,000
Cost of depositing stone and all contingencies, 18 per cent	1,388,520
Fifty ice-piers, at $20,000 each	1,000,000
To dredge entrance-channels, 1,500,000 cubic yards, at 25 cents	375,000
	10,477,520

J. D. KURTZ,
Lieut. Colonel of Engineers.

UNITED STATES ENGINEER OFFICE,
Philadelphia, Pa., February 14, 1874.

APPENDIX W.

ANNUAL REPORT OF LIEUTENANT-COLONEL JOHN NEWTON, CORPS OF ENGINEERS, FOR THE FISCAL YEAR ENDING JUNE 30, 1873.

[Letter of transmittal under Appendix G.]

W 1.

IMPROVEMENT OF THE HUDSON RIVER FROM TROY TO NEW BALTIMORE, NEW YORK.

Extension of Base Island dike for a length of 2,448 feet was awarded in contract to Mr. James D. Leary. The limit of time was December 31, 1873, which was extended to June 30, 1874. This extension was not

effectual, since almost continuous freshets in the river have made it impossible to finish the work. It will be completed in the month of August.

The liabilities on account of this extension are $14,688.

The north end of the Bath dike and the cross-dike connecting it with east bank were repaired at a cost of $387.18.

A portion of the Small Island dike, to close the space from the Jagger Iron-Works, near the city of Albany, to the north end of Bogart's Island, was commenced under contract with James D. Leary. The limit of the contract was December 31, 1873, which was extended to June 30, 1874; but the prevalent high-water of the river has made it impossible to finish this work. It will be completed in August. The length of the portion under contract is 2,580¼ feet, and the liabilities therefrom will be $14,449.40.

The river had begun to encroach seriously upon the face of Schodac Island. The dike which was commenced several years since, to protect this island and connect Castleton and Schodac dikes, was left unfinished, for reasons given in a previous report. To prevent the river turning the dike, a stone wall and dam to the shore were constructed, at a cost of $124.

Cedar Hill dike was partially filled where settlement of the stone had progressed, and other partial repairs made to the dike, at a cost of $147.04.

The direction of the north end of the Middle-Ground dike, at Coeyman's, was slightly changed, at a cost of $146.04. This end of the dike, damaged by collision and much cut up by floating ice, was afterward repaired and iron-sheathed, at a cost of $232.86.

Roah-Hook and Barren Island dikes, at Coeyman's, were filled with stone to compensate for settlement, at a cost of $447.

REPAIRS OF EXISTING WORKS.

Port Schuyler dike has been breached by the ice and collisions. This has been noted in past annual reports, but, as the urgency has not been pressing, it is again mentioned only to introduce the probable cost, which is estimated to be $9,000.

Pile-dike, forming the lower end of the Overslaugh dike, needs repairs and filling with stone.

Probable repairs at Parda Hook dike and at Cedar Hill dike, including stone filling.

Roah-Hook and Barren Island dikes need to be leveled up with stone.

Excepting the repairs of Port Schuyler dike, the other repairs needed would probably cost $1,500.

CONTINUATION OF THE IMPROVEMENTS OF THE RIVER.

The object of the repairs of the Port Schuyler dike would be to diminish its height to a level a little above that of mean high-water. The effect of the high level heretofore held has been, by concentrating the scour at a narrow gorge in the course of the river, to convey gravel and large material to form Round Shoal below. By holding the top, on the contrary, at a low level, the floods easily escape through the back channel, and thus diminish the supply of gravel sent down the main channel. This matter has been referred to in the annual report of 1873.

Much of the flood now escaping through the breaches in this dike returns to the main channel some distance below over the top of a low

dike constructed by the United States in 1867 to connect Hillhouse and Patroon's Islands. The effect of this is bad, as the floods bring over large quantities of sand to fill up the channel, already obstructed by Round and Fish-House Shoals. This return of the waters to the main channel is partly due to the fact that at some period, supposed between 1830 and 1843, dams were built connecting Cuyler's and Patroon's Islands with the west shore, and thus closing the back channel. In order to relieve the main channel of the evil effects of the floods, it will be necessary, besides lowering Port Schuyler dike during its repairs, likewise to raise the level of the pile-dike above named, and to remove the dams across the back channel; for the latter operation, probably, it may be necessary to obtain the consent of the State of New York, as the owners of the islands in question may have some interest in preserving the dams, which serve as causeways or roads to connect their property with the mainland.

Lowering the level of Port Schuyler dike	$9,000 00
Raising the level of the pile-dike to an additional height of 4 feet	10,000 00
Removing obstructions in back channel, probably	15,000 00
	34,000 00

The above includes what, in my judgment, should be applied, besides the works already constructed, to the permanent improvement of that portion of the river between Troy and Albany.

After eliminating, as far as possible, the evil consequences of the freshets by the system above recommended, additional permanent improvement can be secured by encouraging the ascent of the tide, which will entirely depend upon the measures to be taken for the improvement of the river below Albany.

Beside the two railroad bridges already constructed at Albany, a third has been authorized by the legislature. However carefully the distances and dimensions of the piers may have been adjusted, it is impossible, when the number of bridges has been multiplied, to avoid interference with the tides and currents, and one shoal at least has already grown considerably since the construction of the last bridge. The third bridge designed has the additional bad feature of a low level of roadway.

If the third bridge be permitted to be established, the small extent of wharf-line below, and available for vessels, would prove entirely insufficient for the business of the port. The tows for New York are made up below the bridges, and the free area of the harbor below existing bridges is already too restricted for the purposes for which it is intended. It is, in my opinion, a gross violation of the rights of commerce and navigation to attempt the construction of the third bridge as designed, and it should be prevented, if there be power anywhere competent to such end. I conclude this portion of the report by presenting extracts from Lieut. J. H. Willard's report to me, which I respectfully recommend to your notice:

> The subject of improving and enlarging the canals that enter the Hudson is yet in abeyance; but when the various plans for cheap transportation are presented for discussion, the Erie at least will occupy a great share of attention.
>
> * * * * * * *
>
> But from the outset all will have been in vain if the great natural basin into which they discharge is permitted to suffer injury. The Hudson River, from Troy to deep-water, should be considered as the continuation of the canal, and should be kept free and open, ready to take its place in the general scheme of improvement.
>
> * * * * * * *
>
> The great city of St. Louis, a thoroughfare to the West, has one bridge for its accom-

modation; here there are already two double-track bridges, both of which can be controlled by the General Government and by the State, so that there can be no call for another railroad-bridge.

* * * * * * *

The interval between Westerloo Island and the city of Albany should be closed, leaving, however, a slip of sufficient depth for the accommodation of the property-owners. Through this channel water that is needed for the main channel is uselessly drained off to the back channel. The works required for this object would not probably cost more than $6,000.

Small Island dike, a portion of which has already been put under contract, should be extended, as designed, to the head of Bogart's Island, a distance of about 2,000 feet, and will cost $10,000.

The dike spoken of in former reports, and designed to be parallel to the Overslaugh dike, should be commenced at the earliest date; at most, it would be 13,000 feet long, and would cost possibly $78,000.

This work is absolutely necessary to improve the channel at the Overslaugh, over which at mean low-water there has never been an available depth exceeding 8 feet.

The old State dam in this neighborhood should be removed, as recommended in former reports. Estimated cost, $7,000.

Austin's Rock, 1,900 cubic yards, now requires removal. The probable cost will be $26,000. The revetment of Scammerhaun Island, 2,500 feet long, will cost $10,000.

The dike forming a face to Schodac Island should be finished. Estimated cost, 1,900 feet at $4, $7,600.

A dike 3,500 feet long to connect Scammerhaun and Shad Islands would probably be required. Its estimated cost is $17,500. A dike from Shad Island extending down stream 4,000 feet would cost $20,000.

The two dikes above named would fulfill the important object of guiding the flood to intersect the ebb-channel, and thus avoid several cross-overs or shoal spaces which separate the present flood and ebb channels.

The last dike in the order named would also serve to deflect the course of Jolly Creek, which enters the river at the lower end of Shad Island, and forms there a considerable deposit, to the serious inconvenience of navigation.

A dike from the lower point of Barren Island about 5,000 feet long, and parallel to the New Baltimore dike, would cost $32,000. In conjunction with this the beacon-light on the shoal, and opposite to the lower portion of the New Baltimore dike, should be moved to some other place. The site of this beacon-light occupies nearly the middle of the proposed channel, and, being enrocked to preserve it, serves at the present time to maintain the shoal, which it is intended by the construction of the dike to get rid of in whole or in part. The effect of the dike would be to increase the flood action through the main channel, whereas at the present time the first effort of the flood is thrown on the west bank, and it is only by a secondary effort that it is eventually carried up the main channel. In addition to the above, a drag should be used to assist the currents to remove certain portions of shoals and to increase the depth in many places, particularly upon the middle ground at Coeyman's, in the re-entering opposite Barren Island, along the main channel in front of Coeyman's, &c. The cost for two years' service would be about $20,000.

A glance at the map will show the value of the operations recommended from Coeyman's to New Baltimore, in opening the way for the flood-tide, and in throwing the separate flood and ebb channels now existing into one channel.

And the same object is kept in view in the recommended structure at Shad and Scammerhaun Islands and at the Overslaugh.

It will then be perceived that the results arrived at in this report are most important, and must combine in one whole the series of partial improvements already effected in the navigation of this river. What has been herein recommended appears to me, after a careful look over the whole ground, to embrace all that is strictly necessary toward a permanent improvement, and I think the sums asked for to complete this project will develop more visible improvement than all that has hitherto been expended, because the period has at length arrived when full advantage can be taken of the extensive works already built and distributed between New Baltimore and Troy.

Amount of estimated cost of completing the work		$269,600 00
Balance available July 1, 1874	$134 87	
Appropriation approved June 23, 1874	40,000 00	
	40,134 87	
To be paid E. R. Seward, act approved June 23, 1874	7,462 00	
		32,672 87
Amount to be appropriated to complete the work		236,927 13
Amount already appropriated by Congress		730,188 00
		967,115 13
Amount of estimate of 1868		984,304 47

The money available for this year's operations will be devoted, first, to the extension of the Small Island dike to the head of Bogart's Island, and the remainder, which will be insufficient for any large operation, will probably be devoted to raising the level of the dike connecting Hillhouse and Patroon's Island.

The next work which should be undertaken is the improvement of the important channel known as the Overslaugh, upon which no works have been constructed since about 1834.

These improvements consist in constructing a dike parallel to the Overslaugh dike, and in removing Austin's Rock.

The dike will cost	$76,000 00
And Austin's Rock	26,000 00
Total	102,000 00

asked to be appropriated during the next session of Congress.

In regard to the operations above, it is manifest that they go together, and must be completed without delay after once being commenced.

In what has preceded, I have insisted upon the necessity of urging the flood-tide up in greater volume, as upon this depends mainly the improvement. The freshets, except to obviate their evil effects, do not enter properly within the scope of a discussion for the amelioration of navigation within the limits of the river assigned to my charge.

But in order to enable the flood to act with its greatest energy it would not merely be necessary to remove impediments to its course within the district under discussion, for an inspection of the maps show that the volume and energy of this tide are much impaired in the lower course of the river, viz, between New Baltimore and Hudson. At many points in this portion the ebb and flood tides take different channels, while favorable opportunities are indicated, at the same time, for closing one

of the channels into which the course of the river is divided, and compelling the two tides to follow the same course.

The importance of this result upon the improvements of the upper part of the river is obvious without discussion, while the benefits to be gained require no enlargement from language.

The river-bottom between New Baltimore and Hudson is generally wide, entirely too much so for a proper regulation if left entirely to nature, and the result is seen in numerous channels interfering with each other, and in the existence of several shoals which have already demanded the attention of the State of New York for their temporary removal. But this mode of treatment is generally ineffectual except in wasting money, and I therefore recommend that an examination be made of the space extending from New Baltimore to Hudson with the view of ascertaining what measures can be taken to regulate the course of the river, and to improve certain shoal places, as well as the probable cost of such operations.

Financial statement.

Balance in Treasury of United States July 1, 1873	$49,500 00
Amount in hands of officer and subject to his check	11,278 89
Amount appropriated by act approved June 23, 1874	40,000 00
Amount expended during the fiscal year ending June 30, 1874	29,634 63
Amount available July 1, 1874	40,134 87
Amount required for the fiscal year ending June 30, 1876	102,000 00

Abstract of bids for constructing pile-dike in Hudson River, near Albany, N. Y., opened August 11, 1873.

Bidders' names.	Southern extension of Base Island dike, 2,500 feet long.	Dike at Cuyler's Bar, 4,000 feet long.	Total.
Thomas C. Jeffers	$6 70 per linear foot.	$6 20 per linear foot.	$41,550
William Fuller and John B. Marshall	6 04 per linear foot.	5 51 per linear foot.	37,140
David Pereira	5 84 per linear foot.	5 31 per linear foot.	35,840
James D. Leary	6 00 per linear foot.	5 60 per linear foot.	37,400

The bids of Fuller and Marshall and David Pereira were thrown out for collusion and attempt to defraud the Government.

Abstract of contract for constructing pile-dike in Hudson River, near Albany, N. Y.

Contractor's name and residence.	Date of contract.	Subject of contract.
James D. Leary, Brooklyn, N. Y.	August 25, 1873	2,500 feet dike, at $6 per foot. 4,000 feet dike, at $5.60 per foot.

W 2.

REMOVAL OF OBSTRUCTIONS IN EAST RIVER, INCLUDING HELL-GATE, NEW YORK.

The following table exhibits the lengths of tunnels and galleries excavated at Hallett's Point at the end of the fiscal year:

Headings and galleries.

	Feet.		Feet.		Feet.
No. 1	296.36	No. 2*c*	143.07	No. 6*c*	44.55
No. 2	185.76	No. 2*d*	48.40	No. 6*f*	27.00
No. 3	199.98	No. 2*e*	116.10	No. 7*a*	75.75
No. 4	194.53	No. 3*a*	75.88	No. 10*a*	180.85
No. 5	191.25	No. 5*a*	129.51	No. 10*b*	184.28
No. 6	224.08	No. 5*b*	66.25	No. 10*c*	130.65
No. 7	230.58	No. 5*c*	50.25	No. 10*d*	16.25
No. 8	213.92	No. 6*a*	207.58	No. 10*g*	19.50
No. 9	225.59	No. 6*a*, (branch)	15.75	Galleries	2,394.20
No. 10	257.65	No. 6*b*, (branch)	146.80		
No. 2*a*	163.27	No. 6*c*, (branch)	172.44	Total	6,780.67
No. 2*b*	102.04	No. 6*d*, (branch)	50.60		

The work was suspended for want of funds about the middle of November, 1873.

The details of operations for the months of July, August, September, October, and part of November, 1873, are as follows:

Linear feet of drivings of tunnels and galleries		896.35
Cubic yards removed		4,648
Feet of holes drilled by machines, (Burleigh drill)	43,742	
Feet of holes drilled by hand	618	
		44,360
Average number of feet of drilled holes to each cubic yard		9.50
Average number of pounds of nitro-glycerine to each cubic yard		1.10
Number of blasts fired		9,218
Pounds of nitro-glycerine		4,850
Pounds of giant powder		560.50
Pounds of black powder		1,406
Feet of Bickford fuse		39,904
Average feet of holes drilled by each machine per shift of eight hours		30.04
Average depth of holes	feet	4.8
Average cost of linear foot of hole drilled by machines	cents	36.9
Number of drills sharpened for Burleigh drills		12.116
Average cost of sharpening a drill	cents	8.70
Average number of feet drilled to each sharpening		3.60
Expenditure of steel to each foot of hole drilled	ounce	0.44

The appropriations for removing obstructions in the East River and Hell-Gate are not entirely devoted to the tunnels and galleries at Hallett's Point, a considerable amount having been expended for the construction, maintenance, and the operating of the steam-drilling scow, which has been at work, at various periods, upon Diamond and Coenties Reefs in East River, and upon Frying-pan and Pot Rock in Hell-Gate.

There are certain rocks in Hell-Gate, as Shelldrake and Way's Reef, which should be removed prior to the completion of the reef at Hallett's Point, because the existence of the latter reef would protect the machine from rapid currents, and, what is of more importance, from violent collisions.

Coenties Reef, which has been, it is thought, thoroughly broken up, requires but a small sum to complete its removal to a depth of 24 feet. The present least depth above the mass of broken stone is 21½ feet.

It is economical, likewise, to continue the use of the drilling-scow in blasting the channel-rocks, on account of the necessary deterioration of

the scow from the progress of decay, a process which is equally rapid whether the apparatus is kept at work or not.

From the expediency, as just shown, of employing the steam-drilling scow, a proportion of each appropriation must necessarily be diverted from the work at Hallett's Point, and the amount annually granted, $225,000, is found to be entirely too limited for the economical or rapid progress of the important operations to which this sum is applied.

The condition of the work at Hallett's Point is such that there can exist no reasonable doubt of its entire success, and therefore another similar work, intended for the removal of the middle reef, and including reefs under various designations, as Flood Rock, Gridiron, Hen and Chickens, and Negro Head, should be early commenced, as by its removal the width of channel would be increased from 600 to 1,200 feet, and the most formidable obstruction to navigation which exists at Hell-Gate would be obliterated.

For the reasons above given, I ask an appropriation of $600,000 as the sum which could be profitably and economically expended during the year.

The discussion of the last steps to be taken in the removal of the rock has been postponed until the exploration of the whole area of Hallett's Point Reef, by means of tunnels and galleries, should have been first completed; this is nearly done, and it is proper to state in general terms what now appears to be the most rational mode of procedure.

There have been two modes suggested: First. To excavate a chamber or cavity sufficiently large and deep to receive the whole body of the *débris;* and this mode would require the removal of all the stone piers supporting the roof of the excavation, and the substitution therefor of artificial supports of little bulk.

This plan, which appears plausible as well as complete, would, in my opinion, be inapplicable at Hallett's Point. An immense work would remain to be done in taking down the existing large piers under the roof, and in sinking considerably the floor-lines to provide a sufficient cavity, the volume of which should be, at the very least, one and a half times the solid contents of the roof.

The nature of the stratification in thin, vertical sheets renders the work of removal of the piers subject to grave accidents, due to unexpected results during the blasting process. If these piers could be removed by the use of the pick, as was done at Blossom Rock, where the rock was of peculiarly easy manipulation, one of the dangers of removing the piers would be obviated; but the rock is hard at Hallett's Point, and the constant application of blasting is required. Again, to carry out the system of providing a chamber or cavity, the piers, as well as the supports to replace them, must have considerable altitude—in some places 35 to 40 feet—and this altitude would add incalculably to the dangers incident to their removal.

These difficulties and others have formed the subject of consideration for years past, but until the work of the tunnels and galleries used to explore the whole rock and ascertain its condition should be perfected, it did not seem pertinent to enter into the present discussion, which really concerns only the last stage of the work, while on the other hand it was probable that a more mature judgment, based upon a longer experience, would result from the course adopted.

The mode of removing rocks by providing a receptacle large enough to receive the roof has never been applied. It was partially attempted at Blossom Rock, a very small reef, where, if anywhere, the process

would have been applicable, but the engineer, Mr. von Schmidt, abandoned this scheme before it was half perfected, and after blowing up the rock had to remove the *débris* with grapples or divers. The expense by such process, too, at Hallett's Point, would, in my opinion, be much greater than by the second method, which consists in driving a system of tunnels and galleries, having proper drainage, to obtain places for charges of explosives, and in disposing of the *débris* by transportation to other points. In a work upon the removal of Blossom Rock, published by the Engineer Department, there are found two projects—the one by Gen. B. S. Alexander, of the Corps of Engineers, by means of the second method before described, and of date anterior to the project of Mr. von Schmidt described in the same volume, and which differed from the former only in removing the piers or walls between the tunnels, and in providing a deep chamber or cavity to receive the *débris*. The useful idea of perforating the rock by means of tunnels, at least was evidently borrowed by him from General Alexander, and Blossom Rock was removed by the latter's process, for the engineer, von Schmidt, declined to carry out his own, and had to remove the *débris* afterwards by artificial means.

Prior to the date of General Alexander's letter, probably as much as six months, I was engaged in a discussion of the feasibility of removing certain channel-rocks in this locality, by using an iron cylinder to reach from the surface of the water to the rock, and working in this to perforate a shaft into the body of the rock, and drive a system of galleries where charges of explosive compounds to blow up the whole mass could be placed. This process was not applied to the channel-rocks, for the reason that in this harbor the iron shaft would be continually exposed to collisions, and might require a mass of material to secure it from such accidents, out of all proportion with the rock to be removed. But in 1869, as soon as sufficient funds were granted for large operations, the coffer-dam at Hallett's Point was constructed, preparatory to tunneling that reef. At this locality, besides the great extent of the work, there was no danger to be apprehended from collisions.

The mode of blowing up the reef at Hallett's Point would generally be this: to perforate from the inside each pier with drill-holes entirely or partly through its mass; a sufficient number of these being provided to complete the destruction of the pier when fully charged. The charges in the different holes of the same pier to be connected together, and a fuse, composed of a quick explosive, to connect the system of charges in each pier with those of the neighboring piers. By this mode the communication of heat or the electric spark to a few centers of explosion would suffice to propagate it through the whole system; because the explosion of the connecting-fuse would advance more rapidly than the demolition of the rock.

In addition to the charges in the piers, others, confined in strong vessels, might be placed on the inside close against the roof, and be shoved from the floors of the galleries to produce greater effect. The piers might be blown down by charges placed in contact with them; or in the galleries large charges might be placed, sufficient to effect the demolition; but much larger amounts of explosives would be required in such process; whereas the proximity of the work to habitations demands not only that a limited amount of charge be used, but that it be so confined as to perform local work only. Water-tamping, by flooding the galleries, will be used to prevent the flying of fragments of rock. The principle of water-tamping was, I believe, first used by Maillefert, in

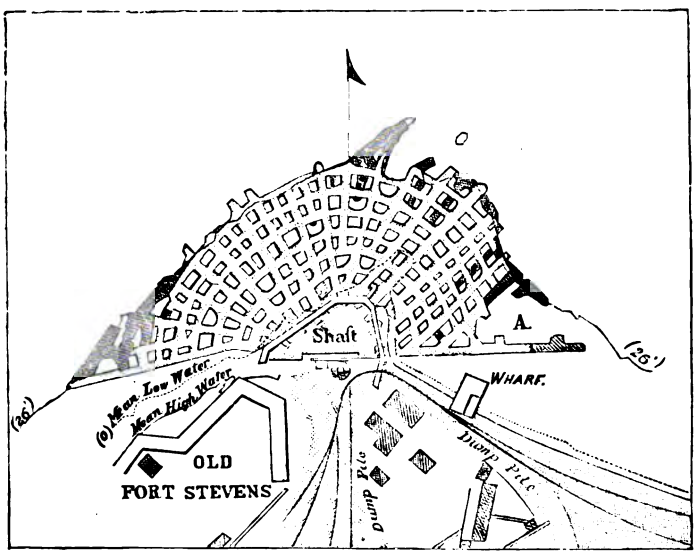
surface-blasting upon the rocks in this harbor in 1851, 1852, and subsequent years, and all engineers who have been since engaged in the removal of submarine rocks have used it.

It is designed to use the quick explosives principally if not exclusively in the demolition of the works at Hallett's Point; and they should be confined in tubes, metallic, gutta-percha, or rubber. As it may require several weeks to charge the system of holes and their connections, if nitro-glycerine or other compounds of which it forms a part be used in metallic tubes, danger might result from corrosion, or from coupling these together. If nitro-glycerine be used in metallic tubes, it might be best to fill these after they have been set up and connected.

The difficulties above sketched would not arise if the tubing be composed of gutta-percha or rubber.

Besides the advantages already given as pertaining to the latter description of tubing, another, that of freedom from leakage, would be more readily secured; and this consideration is a matter of first importance when nitro-glycerine or the compounds in which it enters are used, though not so if gun-cotton be the explosive.

Capt. Wm. H. Heuer, Corps of Engineers, assistant, has continued in the superintendence of the operations at Hallett's Point, where his services have been faithfully and effectively performed.



STEAM-DRILLING SCOW.

The operations of this machine were confined to Coenties Reef, commencing work June 25, and being laid up December 15, 1873.

The cause of suspension of work on that date was the exhaustion of funds available for the work, and was particularly unfortunate, as but little additional cost was needed to bring the level of the rock to the depth required, and there was apparently nothing further to be done than to remove broken rock.

The least depth, which is confined to a small heap of loose stone, is 21½ feet at mean low-water, and the depth proposed is from 24 to 25 feet.

During the period of operations 307 holes, amounting to 2,629 linear feet, were drilled. The diameter of holes at the top was generally 4½ inches and at bottom 3½ inches. The amount of nitro-glycerine expended was 17,127 pounds, and this included likewise the charges of 39 surface-blasts.

The amount of stone grappled and removed from the reef was 2,805 cubic yards, and this does not include the amount, which is unknown, raked from the surface into the deeper water on the sides of the reef.

The operations of the past season were under the superintendence of Mr. J. H. Striedinger, civil engineer, and were faithfully and skillfully conducted.

During the present season the machine will be put to work upon Shelldrake and Way's Reef in Hell-Gate.

ESTIMATE.

The estimate of January 21, 1867, for the removal of certain obstructions in Hell-Gate, Hallett's Point, the Middle Reef, and smaller rocks, as Pot Rock, Frying-pan, Way's Reef, and Shelldrake, amounted to $8,692,645.15.

The mode of operation was drilling into the surface of the rocks, blasting, and removing the *débris*, and the estimate per cubic yard was $44.28, a rate which is thought to be correct for the operations in question.

At a later date, January 3, 1870, a new estimate, based upon the process of tunneling the larger reefs, as Hallett's Point and the Middle Reef, and removing the smaller reefs by drilling from the surface of the water, was made and the average rate per cubic yard fixed at $15 as a minimum, and $20 for the maximun.

The quantities in the Middle Reef and channel, as heretofore determined from old surveys, though only approximate, must be retained, as there are no surveys of recent date sufficiently advanced to furnish a more correct volume.

Reefs at Hell-Gate, 234,491 cubic yards, at $20	$4,689,820
Diamond and Coenties Reefs, letter of March 2, 1868	449,300
Total	5,139,120

The estimate for Diamond and Coenties Reefs in East River should here be added, as it did not appear in the other reports cited above, which had reference to Hell-Gate only.

In conducting the surveys of the reefs and smaller rocks each sounding was separately located by instruments, while the rapidity of the tides caused a suspension of the soundings, except during the periods of slack currents.

Amount allotted or specifically appropriated	$1,440,000 00
Deduct amount reverted to United States Treasury	3,158 55
	1,436,841 45
Balance on hand July 1, 1874	228,922 28
Expended July 1, 1874	1,207,919 17

Expenditures classified.

Excavations at Hallett's Point	$660,427 21
Construction and expenses of steam-drilling scow operating upon Diamond and Coenties Reefs, East River, and Pot Rock and Frying-pan, Hell-Gate	365,278 98
Amount paid to B. Maillefert and others under contract for work upon Shelldrake and Way's Reef, Hell-Gate	69,427 55

Engineering expenses, including surveys of Diamond and Coenties Reefs, East River, Hallett's Point, Middle Reef, Pot Rock, Frying-pan, Way's Reef, Shelldrake, Scaly Rocks, &c., in Hell-Gate, and expenses of steamers	$112,785 43	
		1,207,919 17

The work for the present season will be the continuation of the tunnels and galleries at Hallett's Point and the operations of the steam-drilling scow upon Way's Reef and Shelldrake, in Hell-Gate.

I have to solicit attention to the title of the appropriation approved June 23, 1874, as follows:

For continuing the improvement by removing obstructions in the East and Harlem Rivers at or near Hell-Gate;

which suspends all work upon Coenties Reef, nearly completed, but situated in the lower part of the East River.

The object of that title was to include the work in Harlem River, but I do not think it was understood by those who passed it that it would exclude a most important work which had been included in previous appropriations.

Financial statement.

Balance in Treasury of United States July 1, 1873	$180,000 00
Less amount expended in fiscal year ending June 30, 1873	233 95
Amount appropriated by act approved June 23, 1874	225,000 00
Amount expended during the fiscal year ending June 30, 1874	175,843 77
Amount available July 1, 1874	228,922 28
Amount required for the fiscal year ending June 30, 1876	600,000 00

W 3.

IMPROVING HARLEM RIVER, NEW YORK.

From the appropriation of June 23, 1874, for continuing the improvement of the East and Harlem Rivers, at or near Hell Gate, the sum of $10,000 was allotted, and will be devoted to the removal of obstructions, viz, the piers of the old bridge and small rock off East One hundred and twenty-fifth street.

W 4.

IMPROVING PASSAIC RIVER, NEW JERSEY—BELLEVILLE BAR.

The contractors have continued work on this bar, their contract having been extended from December 31, 1873, to June 30, 1874, and at the end of the fiscal year ending June 30, 1874, they had removed 5,820½ cubic yards of stone and bowlders, and 3,807¼ cubic yards of sand and gravel.

As mentioned in my last annual report, a number of outcroppings of bed-rock of indurated sandstone and shale were developed as the dredging progressed, and this has been found to be the general character of the river-bed all along the line to be dredged. As the contractor was not

under obligation to remove fast rock, measures were taken to drill and blast it as it was developed; for this purpose a small scow was purchased in the month of August, 1873, and fitted up with one of the steam-drilling engines used in connection with the drilling-scow on the reefs in the East River, and was kept at work drilling and blasting until the month of December, 1873, when the ice compelled a suspension of the work.

In the spring of 1874, when the contractor again resumed work, it was found necessary to send the scow and drilling arrangements to the bar to assist them in getting out the rock. The drilling this season has been done with a diamond drill, which gave evidence of being very well calculated for drilling in rock of the character found in this locality. So far as known, all the rock has been broken up and mostly removed, and the contractors will be through with the work by September 1, 1874.

RUTHERFORD PARK BAR.

The work of dredging a cut through this bar, under contract with James Caler, 2,900 feet long, and 50 feet wide on the bottom, to be completed on June 30, 1874, was very nearly finished on that date, and the contract was extended to September 1, 1874, in order to allow him to remove such inequalities as had been overlooked, and to straighten the line of the cut.

Bed-rock of the same character as that found in the Belleville Bar was found in this cut, and it was necessary to make some surface-blasts in order to break it up, so that the dredge could remove it.

Original estimate	$123,924 00
Amount appropriated	70,000 00
Amount expended	46,390 32

Financial statement.

Balance in Treasury of United States July 1, 1873	$45,000 00
Amount appropriated by act approved June 23, 1874	20,000 00
Amount expended during the fiscal year ending June 30, 1874	21,231 70
Amount available July 1, 1874	23,609 68
Amount required for the fiscal year ending June 30, 1876	54,000 00

W 5.

IMPROVING EAST CHESTER CREEK, NEW YORK.

No work has been done on this creek since my last annual report, except some surveys made at the entrance, to ascertain if it would be expedient to apply the money to an improvement of that part of the creek; but as this could not be done advantageously, I have waited until the inhabitants in the vicinity of Mount Vernon could petition the State legislature for power to have land, through which the improvement is to be made, condemned and purchased by a commissioner appointed by the State; this authority has been granted, and the commission are now arranging the matter. I am awaiting the result of their labors to report to the Chief of Engineers a project for the disbursement of the sums available for this work.

Amount asked for fiscal year ending June 30, 1876, for opening new channel above Lockwood's, $35,000.

ORIGINAL ESTIMATE.

Basin, purchase of site, 18 acres, at $150	$2,700
Excavation, to level of mean low-water, 200,000 cubic yards, at 40 cents	80,000
Excavation of cut, 60,000 cubic yards, at 40 cents	24,000
Diking and revetting banks of cut	12,000
Engineering and contingencies	17,800
	136,500
Amount appropriated	25,000

East Chester Creek is in collection-district No. 10.

Financial statement.

Balance in Treasury of United States July 1, 1873	$25,000 00
Amount expended during the fiscal year ending June 30, 1874	4,461 60
Amount available July 1, 1874	20,538 40
Amount required for the fiscal year ending June 30, 1876	35,000 00

W 6.

IMPROVING HARBOR AT PORTCHESTER, NEW YORK.

No work has been done at this harbor during the year; some drawings of surveys have been finished.

Amount necessary to be appropriated to complete the original project	$84,632 00
Estimate, removing rocks and building breakwater	96,632 00
Amount appropriated	12,000 00
Amount expended	9,763 30

Financial statement.

Balance in Treasury of United States July 1, 1873	$2,200 00
Amount in hands of officer and subject to his check	852 69
Amount expended during the fiscal year ending June 30, 1874	815 99
Amount available July 1, 1874	2,236 70
Amount required for the fiscal year ending June 30, 1876, (to complete the removal of sunken rocks)	60,000 00

W 7.

IMPROVING HARBOR AT RONDOUT, NEW YORK.

Under the appropriation of March 3, 1873, contract was made to extend the north dike 1,400 feet. Work was commenced in October, and at the close of navigation 742 feet were completed. When work was resumed in April, the line of dike was changed somewhat, and the total length reduced from 1,400 feet to 1,282 feet, and was completed by June 30, 1874.

Considerable damage was done to the dike during the winter by the ice carrying away about 80 feet of that portion built during the fall of 1873; this was repaired by hired labor. In addition to the dike, a crib was sunk on the line of the dike of the following dimensions: 100 feet long, 25 feet high, 20 feet wide at bottom, and 16 feet wide at top. This was done by verbal contract.

Abstract of proposals for extension of pile-dike at Rondout, N. Y., opened July 7, 1874.

Bidders.	Price.
James D. Leary	$10.29 per linear foot.
Gage & Powley	11.35 per linear foot.
Chas. A. Harrington	120.00 per linear foot.
Clinton Stevens	16.50 per linear foot.

Abstract of contract for extension of pile-dike at Rondout, N. Y.

Contractor's name and residence.	Date of contract.	Subject of contract.	Remarks.
James D. Leary, Brooklyn, N. Y..	July 28, 1873	For 1,400 feet pile-dike.	Work to be commenced by August 10, 1873, and to be completed by June 30, 1874.

It is important that the south dike be constructed and dredging commenced in channel between dikes, and for this purpose the sum of $60,000 is asked for the fiscal year ending June 30, 1876.

ORIGINAL ESTIMATE.

North dike, 748 yards long	$41,600 00
Branch dike, 604 yards long	34,400 00
South dike, 1,277 yards long	59,600 00
Dredging channel 3,000 feet long, 100 feet wide, and 14 feet deep	14,400 00
Contingencies and engineering	22,500 00
	172,500 00
Amount appropriated	$30,000 00
Amount expended	29,160 29

I beg leave to state that, although the completion of the north dike has produced the improvement anticipated, the deepening of the water in a narrow channel along its face, it is nevertheless necessary for the success of the improvement that the other parts of the project, viz, the south dike and dredging, by which a proper width of channel may be secured, should be undertaken with the least possible delay. Without the continuation and completion of the project, the work, in the present unfinished state, will be dangerous to navigation, owing to southerly winds forcing vessels upon the north dike.

Financial statement.

Balance in Treasury of the United States July 1, 1873	$22,500 00
Amount in hands of officer and subject to his check	6,967 31
Amount expended during the fiscal year ending June 30, 1874	15,675 13
Amount available July 1, 1874	839 71
Amount required for the fiscal year ending June 30, 1876	60,000 00

W 8.

IMPROVING CHANNEL BETWEEN STATEN ISLAND AND NEW JERSEY.

Under appropriation of June 23, 1874, of $50,000, it is proposed to commence the construction of the south dike.

Amount asked for fiscal year ending June 30, 1876, for completing south dike	$85,000 00
For dredging new channel, the present channel supposed to be closed, by the construction of the south dike	60,000 00
	145,000 00

This amount asked should obviously be granted in one sum, because the construction of the south dike, which would close the present channel, cannot be completed until the new channel is dredged.

ORIGINAL ESTIMATE.

Dredging and diking	$443,210 00
Amount appropriated	50,000 00

Financial statement.

Amount appropriated by act approved June 23, 1874	$50,000 00
Amount available July 1, 1874	50,000 00
Amount required for the fiscal year ending June 30, 1876	145,000 00

W 9.

SURVEY OF HARLEM RIVER, NEAR EAST RIVER, NEW YORK.

UNITED STATES ENGINEER OFFICE,
New York, February 19, 1874.

GENERAL: I have the honor to submit the following report on the Harlem River survey, made in conformity with the act approved March 3, 1873, for examinations and surveys, specifying Harlem River, near East River, New York.

The Harlem River forms an important passage from the Hudson River to Long Island Sound and New York Harbor. Its upper part has been much neglected, and, in consequence, has been obstructed by artificial obstacles, while the natural ones have been suffered to increase. It is the water-boundary on the north side of Manhattan Island, separating it from the main.

The water-course is, in fact, a narrow sound, continuous from the Hudson River to Long Island Sound; and Spuyten Duyvil Creek is a small stream emptying into this sound near King's Bridge. From Hudson River to King's Bridge the stream is known as Spuyten Duyvil Creek, and as Harlem River from King's Bridge to Long Island Sound. The western or Hudson River entrance is thirteen miles north of the Battery, (New York City,) and the main eastern entrance is in the Hell-Gate passage, between Ward's Point, on Ward's Island, and the foot of East One hundred and sixteenth street, New York City. Besides this last-named entrance are two others—Little Hell-Gate and Harlem Kills. The first is 1,100 yards in length, with an average width of 165 yards, and a minimum depth of 8 feet. The bottom is irregular and rocky, and the current very rapid. The other passage is 100 yards in mean width, and has a minimum depth of 4 feet. The main eastern entrance into Hell-Gate is seven and a quarter miles from the Battery. The Little Hell Gate entrance is eight and a quarter miles, and the Harlem Kills entrance nine miles.

The distance from the Hudson River to Hell-Gate by this passage is eight and a half miles.

Its easy access from the Sound, and moderately easy access from New York Harbor, together with its quiet interior position, would seem to make it a desirable thoroughfare for vessels passing from Long Island Sound to the Hudson River, and, in certain cases, even for those passing between New York Harbor on the East River and the Hudson.

The local trade with the flourishing towns on its banks (now annexed

to New York City) should deserve some consideration as enhancing the importance of the passage. The distance from Peck Slip, on the East River, to the mouth of Spuyten Duyvil Creek, on the Hudson, is nearly the same through Harlem River as by way of the Battery and Hudson River, so that for all places east of this the Harlem River route is the shorter.

The above is compiled from the Harbor Commissioners' Report of the year 1857, pp. 206, 207. There are at present plying between Harlem and the lower part of New York City two steamboat-lines, entitled respectively the Harlem and New York Navigation Company and the Morrisiana Steamboat Company. The Harlem and New York Navigation Company runs four steamboats; total value, $200,000.

For the year 1873 this line carried 1,500,000 passengers, an increase of 234,000 over 1872, and made on an average twenty-three round trips, or forty-six passages per day. The net proceeds from freight were $9,000.

The Morrisiana Steamboat Company owns two steamers, valued at $130,000. These two boats, during the year 1873, carried 1,000,000 passengers, and averaged per day ten round trips or twenty passages. Their net proceeds from freight amounted to $10,000. The above information is from the officers of these companies. With increase of travel these lines intend to put on more boats. On foggy days, trips cannot be made without danger of encountering rocky obstructions. As regards the number and tonnage of vessels plying on the Harlem River, very little can be ascertained, but no doubt exists that a large number frequents this river.

IMPROVEMENT OF THE HARLEM RIVER—RESULTS OF FIELD-WORK.

Two tide-waves of different magnitudes and establishments visit New York Harbor, meeting and overlapping between the upper part of the East River and the western limits of the Sound.

At Governor's Island, owing to the expansion of the tidal basin formed by the upper bay, the Sandy Hook tide reaches its minimum range, having diminished from a mean rise and fall of tides of 4.8 feet to one of 4.3 feet at Governor's Island. Thence toward the Sound the tidal elevation increases steadily, reaching at the west side of Hallett's Point a range of 5.1 feet, and continuing thus until at Throgg's Neck we meet a mean rise and fall of 7.3 feet—the Sound tide. In this course the establishments also gradually approach those of the Sound, being at Hell Gate ferry 1h. 49m., at Throgg's Neck 3h. 21m. later than at Governor's Island. The tidal currents are called into existence by the variations in the different heights of the Sound, their epochs having no direct relations with the local tide, and their velocities being affected by the same circumstances.

The rise and fall of tides is about 5.2 feet at the foot of East One hundred and twelfth and One hundred and twenty-fourth streets, New York City. It increases a little toward Mott Haven, where it is 5.3 feet.

On its way up from East One hundred and twelfth street to Mott's dock the tidal waves experience a retardation of 5½ minutes.

Of the tidal currents, the ebb-current is the stronger in the lower Harlem River; from the east the ebb enters the Harlem River with great velocity through Little Hell Gate and the Harlem Kills, setting strongly toward the New York shore, and forming eddies at its junction with the waters of the Harlem River.

The minimum depth of the improved Harlem River is expected to be

not less than 12 feet at mean low-water. Taking this as the required depth, we find the following obstructions to safe channel-navigation. The obstructions given below were inspected by a competent diver, and specimens of the rocks brought up:

I. Three of the five remaining piers of an old bridge which formerly spanned the Harlem from what is now called the foot of East 114th street, New York City, to the northwest end of Ward's Island. These five piers are numbered on the map of the recent survey as 1, 2, 3, 4, 5; No. 1 being the pier nearest the Ward's Island shore, and No. 5 the one in closest proximity to the Harlem shore.

The three piers, however, which come under the head of obstructions are respectively Nos. 1, 3, and 4. Pier No. 5 has less than the required depth over it, but, by reason of its very close proximity to the shore, it cannot be properly classed as an obstacle to safe channel-navigation. No. 2, having 12 feet and more of water on it, is not included in the system of improvement. Pier No. 1, formed of large stones, is distant 18.7 feet (measured on center line of bridge) from the Ward's Island high-water line, (corner of sea-wall;) 16.7 feet is its maximum depth at mean low-water, 4.8 feet its minimum.

Pier No. 3 is composed of loose stones.

Pier No. 4 is composed of large stones, weighing about three tons, and solidly imbedded together. This pier is distant 36.7 feet (measured on center line of bridge) from the New York high-water lines. The maximum depth of water on said pier at mean low-water is 8.7 feet, the minimum 5.1 feet. Before proceeding farther it would be well to give the history of the "old bridge" in order to determine whether these piers should be removed by the United States Government or by the State of New York.

THE OLD BRIDGE.

On the 20th of February, 1807, at the request of a company engaged in the cotton-trade, a bill was passed by the New York State legislature authorizing the construction of the above-mentioned bridge. (See Webster and Skinner's Laws, vol. 5.)

It was to be built for the advantages of the trade it would afford this company, (prominent among whom were Bartholomew and Jasper Ward,) the owners of a cotton-mill on Ward's Island. The engineer and builder was a Mr. Thomas Lyons, since deceased. The exact date of the construction of this bridge cannot be found, nor is there extant a complete drawing of it. As near as could be ascertained, after much trouble, the bridge was built in 1807. The structure was of wood, 50 feet wide, 25 feet carriage-way, and 12½ feet on each side for the accommodation of passengers. (These few dimensions were obtained from the records in the office of the comptroller of the county and city of New York.) The piers of the bridge, six in number, (as we have every reason to believe,) consisted of cribs sunk in the river.

By the completion of this bridge was connected what is now known as the foot of East One hundred and fourteenth street, New York City, (then part of the estate of Rev. Philip Milledoler,) and the northwest end of Ward's Island.

The bridge remained standing till the 3d of September, 1821, when an unusually high tide, combined with a very strong gale, completely demolished it, nothing remaining but the piers upon which it had rested. These were visible at low-water, and were sufficiently dangerous to be the cause of several accidents. They remained in this condition until the year 1858, when, at the earnest request of Mr. H. P. McGown, president of

the Harlem and New York Navigation Company, the authorities of the city of New York took the matter in hand, and appropriated a sum of money out of the city funds. The contract (for $3,900) for removing these obstructions was awarded to Morris & Cumings. In either August or September, 1858, the contractors commenced operations, and by means of a large rake succeeded in lowering three piers and making a minimum depth of about 12 feet at mean low-water over each. The piers raked down were those before mentioned as Nos. 2 and 3, and another one of which no trace exists at the present day. Those left untouched were the two nearest the New York shore (Nos. 4 and 5) and the one in same proximity to Ward's Island, (No. 1.)

II. Candle Factory Reef lies off the foot of East One hundred and twenty-second street, New York City, 140 feet distant from high-water line New York shore. This rock consist of gneiss vertically stratified. The shallowest sounding gives 1.9 feet on the apex of the rock at mean low-water. The reef rises to a sharp point at its center, and thence shelves downward, giving at the base depths of 8 or 9 feet. Lying as this obstruction does, on the very edge of the steamboat-channel, it is considered a dangerous obstruction. Several accidents have happened. On the 16th July, 1867, the steamboat Sylvan Stream (of the Harlem and New York Navigation Company's line) ran on the reef, and was damaged to such an extent as to sink almost immediately. In April, 1863, the passenger-steamboat Minnie was also sunk by running on the same rock. There have also been accidents to sailing-vessels striking on the reef.

III. Large flat rock, foot of East One hundred and twenty-fifth street, Harlem, 304 feet distant from the Harlem shore high-water line, and 122 feet above the upper corner of the pier. A portion of this rock runs under the pier, but is not here considered, it being the province of the proprietor of the dock to remove that part of it. This rock consists of gneiss vertically stratified. The maximum sounding gives a depth of 11 feet; the minimum, 7.5 feet on the rocks.

IV. Small rock, situated in mid-channel, off foot of East One hundred and twenty-fifth street, opposite entrance to the Harlem Kills, and distant 470 feet from the Harlem high-water line; it is composed of gneiss, of a dip of about 75°. The shallowest sounding reads 9.4 feet at mean low water.

V. Small rock at the mouth of the Mott Haven Canal, about 50 feet from the northwest corner of Mott's dock. It consists of a ledge of gneiss, running in a north-northeast direction, nearly parallel to the direction of the canal. The minimum sounding gives a depth of 3.8 feet on this rock at mean low-water.

PROPOSED PLAN OF IMPROVEMENTS.

Raking alone would not prove a successful means of removing the obstructions to safe channel-navigation formed by bridge-piers, consisting, as they do, of heavy stones in some places, and of strong material, firmly imbedded, in others. Some surface-blasting will be, at first, necessary, in order to reduce the size of the larger stones, and also to start the compact masses, before any successful attempt at grappling can be made. The removal of the remaining rocky obstructions must be performed by means of a systematic process of rock-drilling, blasting, and grappling. The comparatively short distance of these rocky obstructions from the buildings on shore will necessitate the use of small

charges, which will cause these operations to be somewhat tedious and expensive.

Estimate of cost of improvement.

I. Piers Nos. 1, 3, and 4, of old bridge, off foot of East One hundred and fourteenth street, Harlem; 674.2 cubic yards, at $6 per cubic yard.	$4,045 20
II. Candle Factory Reef, foot of East One hundred and twenty-second street, Harlem; 1,149.46 cubic yards, spread over an area of 2,529 square yards, at $72.81 per cubic yard	83,703 00
III. Flat rock off foot of East One hundred and twenty-fifth street, Harlem, 304 feet from Harlem shore; 333.6 cubic yards, spread over an area of 508 square yards, at $97.13 per cubic yard	32,404 00
IV. Small rock in mid-channel, off East One hundred and twenty-fifth street, Harlem, 470 feet from Harlem shore; 23.9 cubic yards, spread over an area of 122 square yards, at $194.56 per cubic yard	4,650 00
V. Small rock at the mouth of Mott Haven Canal; 470.59 cubic yards, spread over an area of 261.2 square yards, at $45 per cubic yard	21,176 55
Contingencies, 15 per cent. of the above	21,896 82
Total	167,875 56

Mr. McGown, president of the Harlem and New York Navigation Company, is entitled to thanks for the kind assistance he lent us, pointing out, at the commencement of the hydrographic survey, the localities of the submerged obstructions, &c.

The survey was executed by Mr. C. de Foresta, assisted by Mr. V. M. Newton, and valuable information was collected by the latter gentleman.

Mr. J. H. Striedinger, C. E., had general charge of the survey and of the plotting of the charts, under instructions from this office. He has compiled all the information available and bearing upon the purposes for which the survey was made.

Respectfully submitted.

JOHN NEWTON,
Lieut. Col. of Engineers, Bvt. Major-General.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

W 10.

SURVEY OF RARITAN RIVER, NEW JERSEY.

UNITED STATES ENGINEER OFFICE,
New York, February 21, 1874.

GENERAL: I have respectfully to forward this report on the Raritan River, together with charts of the survey made in pursuance of the act approved March 3, 1873, for examinations and surveys, specifying the Raritan River, New Jersey, below New Brunswick, including the shoals called the Middle Ground.

The Raritan River, a tidal stream, is navigable from the bay to the city of New Brunswick, N. J., a distance of about fourteen miles. The Raritan River occupies a central position in relation to the great chain of rivers, bays, and canals which form the internal navigation of the Atlantic seaboard, communicating, as it does, on the east with Long Island Sound, and the rivers of New England which flow into it; on the north with the Hudson River, the Erie Canal, the great lakes, the Northern Canal, and Lake Champlain. On the south the Raritan River,

by means of the Raritan and Delaware Canal, communicates with the Delaware River, the Delaware and Chesapeake Canal, and Chesapeake Bay, with Elizabeth River, and Albemarle and Pamlico Sounds, and with the rivers of Virginia and North Carolina.

With exception of the Atlantic Ocean, the Raritan River is the only means of communication by water between the cities of New York and Philadelphia. In the year 1871, the number of vessels leaving the Delaware and Raritan Canal per tide-water, through the Raritan River and Raritan Bay, was 1,545 steamboats, 668 sloops and schooners, and 13,649 canal-boats and barges. In addition to the above, there is a steamboat-communication between New York City and New Brunswick; there are also vessels trading upon the Raritan River other than those going into and through or leaving the Delaware and Raritan Canal.

The aggregate tonnage passing into the Raritan River and through the Delaware and Raritan Canal amounted to the sum of 2,647,430 gross tons during the year 1871.

The said trade has since then highly increased, and is still increasing.

(The above is an extract from the petition of Messrs. James T. Easton and James McMahon, of New York, in their suit with the New York and Long Branch Railroad Company.)

The three maps herewith submitted embrace the navigable part of the Raritan River.

A.—SCOPE OF THE FIELD-WORK.

Tidal observations.

Regular day and night observations were made at tide-gauge I, (New Brunswick,) and at tide-gauge III, (South Amboy,) during two lunations. Simultaneously with the above, day-observations were made at tide-gauge II, (French's Landing.) In addition to these three standard gauges, and in proportion as the field-work advanced, intermediate gauges were set up and used at Martin's Dock, Whitehead's Sand Dock, Whitehead's Dock, Kearney's Dock, and at Watson's Dock. Glass-tube tide-gauges A and B for minute reading were used at Watson's Dock, Sandy Point, and Martin's Dock, (at Perth Amboy,) for measuring the approximate surface-slopes during the current-observations made near the New York and Long Branch Railroad bridge.

Simultaneous tidal observations were for a few days made near, during, and after high and low water stands, and at all the seven gauges.

Currents.

The velocities and directions of tidal currents were observed during a whole ebb and flood, both above and below the New York and Long Branch Railroad bridge. Cylindrical poles reaching from the surface of the water to a depth of six feet below, a depth answering the average draught of vessels navigating at present the Raritan River, were used as floats. The position of these free floats was determined in very short intervals of time by instruments placed at the extreme ends of carefully-measured and well-located base-lines.

Soundings.

The soundings in water exceeding in depth three fathoms were taken by means of hand-lines; those in shallow water by means of poles. Each sounding was located by instrumental observations on shore.

Triangulation.

Three base-lines were carefully measured and connected by triangulation. The magnetic and true bearings of the longest lines were observed.

B.—RESULTS OF THE FIELD-WORK.

1.—*Tides.*

The tidal wave coming round Sandy Hook and passing through Raritan Bay and up the Raritan River steadily increases in range until the rise and fall of tides at French's Landing is 0.36 foot greater than at South Amboy, and 0.49 foot more than at Sandy Hook. From French's Landing up the tidal wave diminishes very little, being at New Brunswick as much as 5.164 feet.

While there is a difference in time of only 17 minutes between the establishments of South Amboy and French's Landing, the passage of the tidal wave from the latter place to New Brunswick, a tortuous and shallow channel five and three-fourths miles in length, is subjected to a retardation of 34 minutes.

The average duration of fall of tides, reckoning from the middle of one stand to the middle of the next, increases from Sandy Hook up to New Brunswick, lasting at Sandy Hook 6h. 15m., at South Amboy 6h. 28m., at French's Landing 7h. 12m., and at New Brunswick 7h. 16m.

Mean high-water level answers the elevation of the salt-meadows through which the river winds its way.

2.—*Currents.*

The flood, which runs in the channel near South Amboy with a velocity of 1.05 nautical miles per hour during the swiftest part of an average tide, gradually diminishes in velocity on its way up. Near Martin's Creek, very little flood-current is experienced. The maximum velocity during an average tide of the ebb-current is 1.60 nautical miles per hour in the channel near Amboy.

The ebb-current diminishes somewhat in swiftness at the upper part of the river, but increases considerably in duration. The river-water is brackish at French's Landing and fresh at New Brunswick.

3.—*Soundings.*

The minimum depth of the Delaware and Raritan Canal, as reported by Mr. I. J. Wistar, general superintendent, is at present 8 feet. "But the Chesapeake and Delaware Canal, over which a large quantity of 'through' or joint traffic is passed, claims a depth of 10 feet. This company, (the Delaware and Raritan Canal Company) is now altering culverts, dredging canal-bed, and otherwise preparing to make the same depth of 10 feet whenever the adjacent rivers shall be in a condition to carry the same." (Letter of Mr. I. J. Wistar, general superintendent, Appendix C.)

Hence, soundings showing in the river-channel a less depth at mean low-water than 8 feet indicate present obstructions, while those showing depths less than 10 feet mark out the points for improvement of the channel when the contemplated deepening of the canal shall have been effected.

The minimum width of the river-channel should not be less than 200

feet, thus allowing the large tows, which can just get through the 100-foot draws at Perth Amboy, to pass each other safely on the river above the bridge.

Taking these considerations as a basis, we find the following obstructions to navigation:

1. Shoal water in the river above the canal-locks at New Brunswick. (Five miles above New Brunswick a dam is built across the whole width of the river for the purpose of feeding the canal with water. This section of the Raritan River acts as a valuable tidal basin to the river.)

2. A gravel, sand, and mud shoal, narrowing the channel-width, commences about 160 feet below the New Brunswick locks. The custom of the Delaware and Raritan Canal Company of dumping the material dredged in the canal over the tow-path, from whence it rolls down the steep embankment, and is carried down and deposited by the river-current below New Brunswick, has most likely contributed to if not formed this shoal.

3. Rocks 300 feet below the New Brunswick locks. They consist of red shale, and project into the channel from the steep south shore of the river, narrowing the channel, and endangering vessels, which are apt to be carried on them by the ebb-currents setting toward the concave shore.

4. A ledge of rocks 3,300 feet above Martin's Dock commences, about 1,200 feet long and 100 feet wide, and, running parallel to the concave north shore of the river, reduces the channel-width considerably.

5. Opposite Martin's Dock there is a reef of rock in the middle of the river.

6. Shoal water below Widmar's Dock and above Lawrence's Creek. This obstruction consists of gravel and sand.

7. Near Whitehead's Dock is a reef of rocks covered with sand, lying in the middle of the river.

8. The "Middle Ground" is a very extensive gravel and sand shoal below Crab Island, and is due to the sudden expansion of the cross-section of the river.

9. The "Stakes" present a tortuous, shallow, and changeable channel to the navigator.

This obstruction is due to various causes, viz: the non-coincidence in the paths of the strong ebb and flood currents; the great increase in the width of the cross-section of the river; and, finally, to the outlet of Red Root Creek.

Comparing the hydrographic survey of 1851 with the recent survey, one finds a rather increased depth in a generally wider channel, due partly to the stirring of the bottom caused by the numerous steamers passing through, and in some cases to the construction of docks from the shore, whereby the cross-section of the river has been contracted and the scour increased.

In presenting this report of the obstructions to navigation, with the charts and information relating to the tidal flow and rise from New Brunswick to its outlet, the capacity of the river for improvement becomes evident. The high range of tides at New Brunswick, obtained against the serious obstacles of rocky shoals and sharp curves in the course of the river, manifests the energy of the tidal flow.

It is fair to presume, therefore, that the removal of these impediments will increase the flow, and at the same time, by decreasing the duration of the ebb, add to its scouring effect.

The construction of the dike, indicated approximately in position upon the chart, and extending from a point below the mouth of Red

Root Creek to a short distance above the head of Crab Island, by its effect in the removal of certain shoal spaces in the channel, and concentrating in the same direction the tidal flow, seems to be the first important element in the general improvement of the river.

The next would be to strengthen the course of the river by excavating a new channel which should cut off certain sharp and deep curves at present existing.

But as the amount devoted to the survey was not adequate to the necessary examination, by borings, of the proposed new route of the channel, and as other questions relating to the ownership of the land, &c., would need inquiry, it has been deemed expedient at this time to glance merely at what is considered the next important step in the improvement. No estimate, of course, can now be presented for such excavation; but should Congress grant money for the improvement of the river, I would recommend that a careful comparison be made of this plan, as to cost and advantages, with the same elements, contingent upon following the present course of the river.

The obstacles existing in the river from Crab Island to New Brunswick have already been enumerated in this paper, and it is proper now to present the estimates made for their removal, including the cost of the dike and excavations between Crab Island and Red Root Creek.

The estimate to secure a depth of 8 feet at mean low-water is $1,707,042.58; to secure a depth of 10 feet at mean low-water, $2,093,662.05. The details are given in Appendixes D and E. It is not certain that the excavation of the tidal basin estimated for in the last project would be necessary, at least to the extent there given; the funds available having been exhausted before a survey of that portion of the river above New Brunswick, which would constitute the location of the basin, could be made, renders that portion of the estimate open to an amendment.

It is proper here to state why the amount allotted to this survey failed to supply all the information desirable. After the allotment was made, the expenses were increased by the survey, and exact current-observations taken at the site of the railroad-bridge then building near the mouth of the river; the necessity for this having arisen after the apportioning of the amount for the Raritan River.

An inspection of the estimates (Appendixes D and E) shows that the great cost of the improvement will principally be due to the larger amounts of rock to be excavated, which lie above Whitehead's Sand Dock, and that, excluding the rock, the cost of improvement up to the dock above named would be about $200,000.

The question then naturally occurs, should the United States spend nearly two millions for the rest of the improvement, or should the Delaware and Raritan Canal Company push the outlet of their canal as far down the river as Whitehead's Sand Dock?

A third estimate for 10 feet in depth up to Widmar's, and thence for a depth of 8 feet to New Brunswick, would amount to $1,726,210.77, which is very little more than the amount of the first estimate given.

I have already reported, by letter of November 18 last, upon the new railroad-bridge at the mouth of the river, and hope, should experience demonstrate the inconveniences and impediments offered by this structure to navigation to be serious, that no pains will be spared by the Government to have it removed. Perth Amboy is the nearest collection-district.

The survey was executed during the fall of 1873 by the parties of Messrs. A. Zoller and E. A. Giesler.

Mr. Julius H. Striedinger, C. E., was in general charge of the survey

and plottings, and to him I am indebted for the compilation of the information deduced from the survey and for a calculation of the quantities in the estimates.

Mr. Francis B. Stevens, general superintendent of the Camden and Amboy Railroad Company, is entitled to thanks for the kind assistance he lent us in pointing out the localities of the submerged obstructions, &c., at the commencement of the hydrographic survey.

Respectfully submitted.

JOHN NEWTON,
Lieut. Col. of Engineers, Bvt. Major-General.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

Commercial statistics.

APPENDIX A.

COLLECTOR'S OFFICE DELAWARE AND RARITAN CANAL,
New Brunswick, N. J., December 5, 1873.

Number of steamers, sailing-vessels, boats, and rafts passing the outlet-lock at New Brunswick (bound east) during the season of 1871:

Steamers	1,545
Sailing-vessels	668
Canal-boats	13,215
Rafts	434
Total	15,862

Total number of tons passing through the Delaware and Raritan Canal during the season of 1871:

	Tons.
Eastward	2,647,430
Westward	406,427
Total	3,053,857

APPENDIX B.

COLLECTOR'S OFFICE DELAWARE AND RARITAN CANAL,
New Brunswick, N. J., December 5, 1873.

Statement of articles carried through the Delaware and Raritan Canal during the season of 1871:

2,172,751 tons of coal, at $4	$8,691,004 00
502,279 linear feet of tie-timber, at 10 cents	50,227 90
1,802,286 cubic feet of square timber, at 40 cents	720,914 40
13,553,782 feet, board-measure, at 5 cents	677,689 10
1,003,008 bushels grain and feed, at $1.25	1,253,760 00
238,707 barrels of flour and corn-meal, at $4.50	1,074,181 50
61,729 tons of iron, at $60	3,703,704 00
405,082 tons of merchandise, at $60	24,304,920 00
	40,476,436 90

APPENDIX C.

DELAWARE AND RARITAN CANAL,
(Pennsylvania Railroad Company, lessee,)
Philadelphia, January 3, 1874.

DEAR SIR: I have your favor of the 31st ultimo, inquiring the designs of the company in reference to the draught of water in the Delaware and Raritan Canal.

The new lock at New Brunswick is used for laden boats, and the old one for light boats. It is considered that we now have a *minimum* depth of fully 8 feet throughout the canal.

But the Chesapeake and Delaware Canal, over which a large quantity of "through" or joint traffic is passed, claims a depth of 10 feet.

This company is now altering culverts, dredging canal-bed, and otherwise preparing to make the same depth of 10 feet, whenever the adjacent rivers shall be in a condition to carry the same. A large amount of money has been already expended for this purpose in anticipation of improved river navigation, and such work is now in progress.

We sincerely hope that your report will induce the necessary action on the improvement of the Raritan River, and especially that it may authoritatively express the great injury to the heavy and increasing commerce of the Raritan, which is being, and will be, caused by the completion of the bridge at South Amboy on the present plans.

Very respectfully,

I. J. WISTAR,
General Superintendent Canals.

Gen. JOHN NEWTON,
Lieutenant-Colonel Engineers, U. S. A.

APPENDIX D.

Estimate of cost for permanent improvement for an 8-foot channel at mean low-water, rock-excavation extending to a depth of 10 feet at mean low-water.

Gravel, sand, and mud shoal below New Brunswick locks, 52,700 cubic yards, at 35 cents	$18,445 00
Rocks 300 feet below New Brunswick locks, 2,399 cubic yards	76,768 00
Ledge of rocks 3,300 feet above Martin's Dock, 17,504 cubic yards	542,624 00
Reef of rocks opposite Martin's Dock, 4,672 cubic yards	182,208 00
Reef of rocks covered with sand near Whitehead's Dock, 11,509 cubic yards	497,188 80
Middle-ground, 55,505 cubic yards, at 35 cents	19,444 25
Stakes, 15,528 cubic yards, at 35 cents	5,434 80
11,400 feet of dike, at $12.48 per running foot	142,272 00
Contingencies, 15 per cent. of the above	222,657 73
	1,707,042 58

APPENDIX E.

For a 10-foot channel at mean low-water.

Dredging tidal basin, 648,000 cubic yards, at 40 cents	$259,200 00
Shoal commencing 160 feet below New Brunswick locks, 225,051 cubic yards, at 35 cents	78,767 85
Rocks 300 feet below New Brunswick locks, 2,399 cubic yards	76,768 00
Ledge of rocks 3,300 feet above Martin's Dock, 17,504 cubic yards	542,624 00
Reef of rocks opposite Martin's Dock, 4,672 cubic yards	182,208 00
Shoal below Widmar's Dock, 14,400 cubic yards, at 35 cents	5,040 00
Reef of rocks covered with sand, near Whitehead's Dock, 11,509 cubic yards	497,188 80
Middle-ground, 55,555 cubic yards, at 35 cents	19,444 25
Stakes, 15,528 cubic yards, at 35 cents	5,434 80
Dike, 11,400 feet long, at $13.50 per running foot	153,900 00
Contingencies, 15 per cent. of the above	273,086 35
	2,093,662 05

APPENDIX X.

ANNUAL REPORT OF MAJOR G. K. WARREN, CORPS OF ENGINEERS, FOR THE FISCAL YEAR ENDING JUNE 30, 1874.

ENGINEER OFFICE, UNITED STATES ARMY,
Newport, R. I., July 1, 1874.

GENERAL: I have the honor to submit the annual reports of improvements and surveys of rivers and harbors under my charge during the fiscal year ending June 30, 1874.

Very respectfully,

G. K. WARREN,
Major of Engineers, and Bvt. Maj. Gen. U. S. A.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers. U. S. A.

X 1.

HYANNIS BREAKWATER, MASSACHUSETTS.

During the past fiscal year, the appropriation of $10,000 made by the act of Congress approved March 3, 1873, has been expended in the rebuilding and repairing of about 220 feet of the west end of the breakwater.

This work has been conducted with especial reference to making the wall above low-water as solid as possible so that it may best resist the force of the waves, and to bringing the slopes under water up to the angle required to insure permanence, which we think is attained here by making the seaward slope 1 upon 2, and the other 1 upon 1.

The west end, for the length of 220 feet, is now in a proper condition, but, as stated in my last report on this improvement, the remaining length of the breakwater is in an unsafe condition below low-water. Many gaps exist in the seaward slope, which, together with its steepness, demand early repairs to prevent a breach in the parapet.

The estimates given below are for this purpose.

4,000 tons of riprap granite, at $3.50 per ton	$14,000 00
Superintendence, &c., 10 per cent	1,400 00
	15,400 00

I deemed it advisable to make a survey of the harbor, sheltered by the breakwater, for the purpose of ascertaining the need and probable cost of enlarging the anchorage-ground by dredging, and herewith transmit a map of the same, and also the report of Mr. P. M. Blake, assistant engineer, who had charge of the work.

I find that a greater depth exists than shown on the Coast Survey chart of Hyannis Harbor for 1850, while the area available for vessels drawing more than nine feet is sufficiently large at present for the use of the coasting-trade.

All that is now needed to make this work permanently safe is a sufficient amount of riprap properly placed, and the appropriation of $5,000 for the present year will be used, so far as it will go, toward

the accomplishment of this object. I estimate that $10,000 more will be required to complete these necessary repairs, and urge that an appropriation for that amount be made for the fiscal year ending June 30, 1876.

The removal of the light-house, as suggested in my former report, from its present position to the east end of the breakwater, is again recommended.

Hyannis is in the Barnstable collection-district. Barnstable is the nearest port of entry. The amount of revenue collected there during the fiscal year ending June 30, 1874, was—

Financial statement.

Balance in Treasury of United States July 1, 1873	$10,000 00
Amount appropriated by act approved June 23, 1874	5,000 00
Amount expended during the fiscal year ending June 30, 1874	9,885 16
Amount available July 1, 1874	5,114 84
Amount required for the fiscal year ending June 30, 1876	10,000 00

Report of Mr. Percy M. Blake, Assistant Engineer.

ENGINEER OFFICE, UNITED STATES ARMY,
Newport, R. I., June 18, 1874.

SIR: I have the honor of submitting the following report on the improvement of the breakwater at Hyannis, Mass., authorized by act of Congress approved March 3, 1873, appropriating $10,000 for the improvement of Hyannis Harbor.

A survey of the breakwater made in April, 1873, showed the need of adding riprap to the slope under water throughout its length, even where the part above low-water had been in late years repaired, and built up to the required height above high-water, the seaward slope in places being steeper than 1 upon 1. About 220 feet of the west end, where no repairs had recently been made, was but a few inches above high-water, and the stones lay in a very irregular manner.

A section of the proposed improvement was prepared, in which the height of the capping above mean low-water was the same as that of the portion already finished, and the outer slope was 1 upon 2.

Proposals for furnishing in place about 1,930 tons of best granite, as regarded durability, were advertised for on June 19, 1873, and the lowest bidders were Messrs. Dawson, Tank & Co., of New London, Conn., who became the contractors for the work at $4.40 per ton of 2,240 pounds, to be measured in vessels gauged by the engineer in charge of the work.

In obedience to your orders, I went to Hyannis August 26, 1873, to superintend operations. The first load of stone was delivered August 27, and the contractors continued to deliver the stone in accordance with the terms of the contract until November 4, when the uncertainty of the weather stopped further work.

During 1873, 1,032 tons of stone were delivered and 116 feet of the west end finished, and capped with heavy stone laid as headers, as specified in the contract.

Work was resumed [again] April 27, 1874, and continued till June 15, 1874, when a length of 217 feet was built up to the required level, and finished off square at the extreme west end. Both slopes under water for the same length, 217 feet, and the inner slope for 50 feet more, were repaired to the width required by the new section. The work of delivering stone was then stopped, as the appropriation was about expended.

During this season's work, 674 tons of stone were delivered by Messrs. Dawson, Tank & Co., making a total for them of 1,706 tons. Of this amount, about 400 tons were used on the outside slope, about 200 tons on the inside slope, and the remainder, 1,103 tons, were used above low-water. The capping-stones, or top-headers, weighed about 350 tons, leaving 756 as the amount built into the wall.

The plans adopted for the improvement, together with the monthly progress, are shown on accompanying sketch.

Although symmetrical in its appearance above low-water, the breakwater east of where this last appropriation was used is not yet complete below that level. To make this so, the slopes below low-water should be built up so as to conform in section with that part finished during the past year. With such a seaward slope as this portion now has, it would not be surprising if some heavy southerly storm should make a sudden and wide breach in it.

Heavy ripraps should be put in for 930 feet on the outside, till the slope becomes the required one of 1 on 2.

From sections prepared from data collected during the survey of April, 1873, I estimate that 3,635 tons of stone will be required to bring the outside to the required slope, while fully 365 tons more will be needed to dress the inside slope to 1 on 1, and fill up holes discovered by the sounding-pole. This will make the amount yet required about 4,000 tons.

To be thoroughly effective, the stones should not weigh less than one and a half tons each.

During the progress of improvement, I made a survey of the harbor of Hyannis, under your direction, and platted the same on a scale of $\frac{1}{2400}$.

The length of shore-line mapped is 1.9 miles, and the area sounded over covers the anchorage-ground protected by the breakwater, and which is, in fact, all of the available basin for vessels drawing more than 9 feet.

All soundings were located by triangulations from measured bases on shore. The breakwater was located by repeated triangulations from nearly every survey-station. The plane of mean low-water, rise and fall of tide, &c., was determined from a record of nine days, the gauge being read every ten minutes from 7 o'clock in the morning till 6 at night, and the soundings taken were reduced to this plane. The mean rise and fall as thus determined was 3.11 feet, and agreed very nearly with the figures obtained from the tide-tables of the Coast Survey for 1874, the latter being 3.2 feet.

The mean low-water plane was referred to underpinning of light-house, that being the nearest substantial object, and is 25.529 feet below the top of granite block in underpinning 3.5 feet east of east side of window, on south side of keeper's house.

The contours on the map show a steep bank just east of and within the entrance to the harbor, which is a source of annoyance to vessels entering or leaving the basin. Two range-buoys on either end of this bank would be of great service to sailing-masters.

The point of land at Hyannis port is wearing away slowly, and a part of the material is no doubt carried along the shore in each direction.

From the evidence of those living near the harbor, and those familiar with the various depths along the shore, it would seem that a very perceptible shoaling is taking place to the west of the railroad-wharf. It is, however, in an unimportant part of the harbor, and until it extends to the end of the wharf it can in no way affect the amount of local commerce.

Of the value of Hyannis Harbor as a port of refuge much has been said, and its claims are well known. Its great value to ship-owners and sailing-masters depends largely upon the condition of the breakwater. It is probable that when this is once in the condition for which we have estimated it will need no further repairs for a long time.

Yours, respectfully,

PERCY M. BLAKE,
Civil Engineer.

Gen. G. K. WARREN,
Major of Engineers, U. S. A.

X 2.

EDGARTOWN HARBOR, MASSACHUSETTS.

Nothing has been done here since the date of my report, of March 31, 1874, giving a full account of our operations during the previous working-season. It is earnestly recommended that all the remaining funds be applied to surveys and investigations at points not heretofore satisfactorily determined, and upon which the propriety of our operations thus far materially depends. I give below the collection-district, the revenue collected, and the financial statement, after which I request that my report dated March 31, 1874, and accompanying papers, be appended.

Edgartown is in Edgartown collection-district, and is a port of entry. The amount of revenue collected there during the fiscal year ending June 30, 1874, was—

Financial statement.

Balance in Treasury of United States, July 1, 1873	$15,000 00
Amount in hands of officer and subject to his check	4,364 81
Amount expended during the fiscal year ending June 30, 1874	17,989 33
Amount available July 1, 1874	1,375 48

SPECIAL REPORT ON IMPROVEMENT OF EDGARTOWN HARBOR, MASSACHUSETTS.

ENGINEER OFFICE, UNITED STATES ARMY,
Newport, R. I., March 31, 1874.

GENERAL: I have the honor to transmit herewith my report and that of my assistant engineer, Mr. H. S. Van Ingen, with a map, giving a full account of the operations during the season of 1873, for improving the harbor of Edgartown, Martha's Vineyard Island, Mass.

The plan proposed was carried out, but it failed entirely to accomplish the object intended, and all the appropriation has been expended, except about $1,300, which is barely enough to make a much-needed survey.

Had the operation succeeded, no further means would have been required, and as the result had not been reached when the last annual estimates were submitted, no further appropriation was asked for.

It seems to me proper that this report should be at once submitted to Congress, so that with the knowledge before that body it will be able to decide what further course to take. I have prepared this report as soon as practicable.

Very respectfully,

G. K. WARREN,
Major of Engineers, Brt. Maj. Gen. U. S. A.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

INTRODUCTION.

The improvement designed for the harbor of Edgartown was to be effected by re-opening Cotamy Bay to the Ocean by an artificial cut through Cotamy Beach, thus restoring the circulation of the tides in this harbor as it existed prior to the closing of the natural outlet through Cotamy Beach in 1869.

The operations were confined to digging through the beach and through the contiguous shoal in the bay. The work was conducted with care and energy, aided by the most experienced men of this part of our coast whose services we could procure.

The amount of labor expended and material removed were equal to our expectations, and the cut was carried entirely through the shoal and beach.

It was designed to throw it open at the time of a favorable high tide in the bay, but a very feeble tide in the bay occurred at the time we were ready, and the next high tide in the ocean coming with a violent storm broke into the cut. The velocity of the current was very great, as it had a head of at least four feet.

The current rapidly widened the cut but did not carry the sand out of it, and, on the change of the tide, the ocean-waves closed the opening on that side. Efforts were made afterward to open the cut with the outflow of the bay-tide, but the waves each time closed it up at the period of slack-water.

The difficulties of the undertaking have not been fully appreciated. As far as I know, no such attempt has succeeded anywhere in this country. All the artificial openings that have been made through

ocean beaches have been from fresh-water ponds, with a large constant head of water, independent of the intermittent action of the tides.

The end sought not having been reached, it becomes important, before proceeding to further efforts, that we should, *first*, fully reconsider the original plan and the data on which it is based; *second*, make as complete a statement as possible of the operations carried on to realize it; *third*, present the subject as thoroughly as we can by the aid of the additional data obtained in these operations, with the modifications of the plan which seem called for; *finally*, to discuss the importance of the object to be accomplished, concluding with such recommendations as we feel justified in making.

The report will, therefore, be separated into chapters, arranged as follows.

Chapter I.—History of the undertaking, from its inception, with data on which plan of operations is based.

Chapter II.—Amount of the operations for carrying out the plan, with the results and observations.

Chapter III.—A somewhat extended presentation of the physical features and forces concerned in the formation of Cotamy Beach, and in making and closing openings through it, with a new project for making an opening.

Chapter IV.—A brief discussion of the importance of the objects to be accomplished, with recommendations for further surveys.

Conclusion.—Recommendations as to further appropriations.

Appendix.—Report of H. S. Van Ingen, civil engineer, assistant on the work.

CHAPTER I.

HISTORY OF THE PROJECT OF OPENING COTAMY BEACH.

The first publication on this subject with which I am acquainted is in the Sixth Annual Report of the Board of Harbor Commissioners, published in January, 1872. This report is made to the legislative bodies of the State of Massachusetts, the commissioners being Josiah Quincy, Darwin E. Ware, F. W. Lincoln, J. N. Marshall, and W. T. Grammer. The report says:

> The attention of the board was called early in the season (that of 1871) to the closing of the outlet through Cotamy Bay, in Edgartown, about two years ago, (that is, in 1869.) * * * The effect of the destruction of the outlet was to destroy the circulation of the tides through the harbor, (Edgartown Harbor,) diminish the scour, and induce a tendency to shoaling. The question to be investigated was whether, by artificial means, the outlet could be made again and the tidal effects restored, and when and under what circumstances this outlet should be made. * * * These inquiries were so important, so difficult, and so technical that the board applied to Prof. Benjamin Peirce, the Superintendent of the United States Coast Survey, for his co-operation in making the investigations.

The commissioners then quote from his letter in response as follows:

> The vicinity of Edgartown has been, for many years, interesting to the Coast Survey because of the changes there in the outer beaches, and because of the remarkable tidal phenomena which occur there. As long ago as 1846, Lieutenant (now Rear-Admiral) Charles Henry Davis called the attention of scientific men to the physical changes that were in progress along the shores of Nantucket and Martha's Vineyard, and, in the same year, Assistant H. L. Whiting made his complete topographical survey of the island and its shores.
>
> My own connection with these particular studies goes back, officially, as far as 1855, when the problems arising from Mr. Mitchell's tidal investigations were referred to me forsolution by my predecessor.

The board gave the topographical survey to the charge of Prof. H. L. Whiting, and the physical hydrography to Prof. Henry Mitchell, and the report says:

They brought to the work a particular interest and preparation.

The report of Prof. Whiting, Assistant United States Coast Survey, made to the Superintendent of the United States Coast Survey, was published as an appendix to the commissioners' report, and since published in the United States Coast Survey, annual report for 1869. From this I take the following:

The comparison of the surveys just made with those of previous dates (1846, 1854, 1855, and 1856) * * * affords data for most interesting study. * * * At the time of my first survey, in 1846, the opening through Cotamy Beach was at the eastern corner, so to speak, of the bay, and was formed by Chappaquiddick Island and the east end of the beach. It was about 2,000 feet in width, and within the opening were two small sand islands.

The condition of the inlet corresponded, in its general location and width, to that shown on Des Barre's maps of 1776. The resurvey in 1856 was made to determine the position and dimensions of the new opening which was reported to have been made in a then recent storm. This survey showed that great changes had taken place since 1846. The old inlet had worked about one mile to the eastward of its former determined site and the point of the beach had lapped by the end of Chappaquiddick over half a mile; about 2,300 square feet of the southwestern face of the island had washed away; instead of being an opening 2,000 feet wide directly opposite the waters of the bay, it was narrowed to one about 500 feet wide, confined between the fast land of Chappaquiddick and the beach, and the waterway between the ocean and the bay was about 3,000 feet in length. The new inlet had broken open opposite the middle of the bay and was about 1,400 feet in width.

"Quite reliable local information concerning the intermediate changes," Professor Whiting says, was obtained by him, in substance as follows: Soon after the new or west opening formed in 1856 the east opening closed. This remaining opening, "following the law of motion which seems to govern all the inlets on the south side of the island," began to move eastward, passed the position of the inlet which had closed in 1856, and continued on till the point of beach forming its outer chop reached a point in line with the general trend of the east shore of Chappaquiddick, where the rapid tidal current of Muskeget Channel checked its further progress. This opening gradually narrowed, "until, at the occurrence of a storm and tide favoring the action, the most easterly portion of the beach was beaten in upon the island by the ocean waves," and the opening closed. This took place in 1869.

There is a tradition, which Professor Whiting refers to, that once before, for a short time, in the early part of this century, the beach was continuous as it now is.

The length of this beach from east to west is about three and a half miles, with an average width of 450 feet.

Professor Whiting's plan of re-opening the beach I give in his own words, for it essentially embraces all the features of the plan attempted, and although I do not think his ideas have had a favorable trial, I believe considerable more difficulty lies in the path of success, than would be inferred from its most careful perusal. It is as follows:

The most favorable point at which to re-open Cotamy Beach seems to be at or near the west end or head of the bay.

The arguments in favor of this location are as follows:

1st. The greater length of time that the inlet will probably remain open, assuming

that it will move from west to east as fast, and close as soon after reaching its eastern limit as the former inlets have done.

2d. The fact that this contracted section of the bay, by confining the tidal currents between the main land of the island and the beach, as they flow to and from the actual inlet favors the formation and maintenance of a channel through the shoal-ground bordering the beach into the deeper waters of the bay.

3d. Economy in cutting through the beach, as the cross-section at this point is about the minimum.

"Although an opening through the beach sufficient to merely start the water running, if made at the time predicted by Professor Mitchell,* may and probably will create a natural inlet, and such an inlet may answer the physical demands required to restore the tidal circulation through the harbor; still the uncertainty of a single tide doing the required work, and the contingency of an intervening storm or ocean swell preventing the continued action of the succeeding tide, render the scheme of depending upon the scouring power of the tide alone a questionable one, unless accompanied by a prepared pathway for it as far through the beach as practicable, and of such a width as shall at once secure, when opened, a stream of considerable volume.

Apart from the physical importance, an effect of opening an inlet through the outer beach, there are difficulties of navigation which such an inlet only would not relieve.

As seen on the map or sketch which Professor Mitchell and myself jointly append to our reports, there is a range of shoal-ground bordering the beach and extending from east to west along the entire south front of the bay. Professor Mitchell has stated in his report that this shoal-ground has increased within the last fifteen years by the amount of about 1,000,000 of cubic yards. This coincides with the popular opinion of the constant accumulation of material upon this ground, which is now so extensive and so shoal, that it is difficult for the peculiar class of boats required for the outside fishing and pilotage to cross it; in fact, they cannot do so except by one or two tortuous and imperfect channels.

If the channel-way through this shoal-ground were made in connection with a new inlet through the beach, it would, of course, give great relief to the boating interest, both for pilotage and fishing. Here again the western section of the bay, before alluded to, presents naturally favorable ground for such a channel, by improving what was once probably a natural channel leading to some former inlet.

* * * * * * *

As a basis for the general dimensions and character of a channel and inlet, as proposed, I have taken a width about equal to the narrowest section of the natural passage-way between the harbor and bay, which is about 300 feet. This is not wider than desirable for a boating channel. The depth is regulated by the class of boats in general use, which require about 4 feet at mean low-water. As before stated, there are in this part of the bay the traces of a former channel through this shoal. By following the general course of this old channel and removing such portions of the shoal as in places now block it up, a passage-way 300 feet wide and 4 feet deep may be obtained by the excavation of about 41,000 cubic yards of the material of the shoal. A corresponding excavation through the beach to the level of mean high-water only, which is probably all that will be needed to insure a successful inlet, will require the removal of 14,000 cubic yards of sand.

* * * * * * *

I had but a small party organization, and am indebted to Professor Mitchell and Mr. Marindin for many favors and much assistance in the execution of my field-work.

At this point in this history the bearing of certain comments on this plan can be more properly introduced than elsewhere, although in certain respects it would be well to reserve them till after the data of Professor Mitchell's report have been presented.

This division of the subject in two reports increases somewhat the difficulty of understanding the engineering questions involved.

Professor Whiting's plan depends upon the nature and extent of the tidal influences, but we find no allusion to these in his report, except in the one case of his reference to "the time predicted by Professor Mitchell."

There is here a dual derivation of the tides, which produces the most complex phenomena, and the different levels on the opposite sides of the Cotamy Beach constitute the foundation on which the success of the project for opening the beach artificially is based.

* This will appear further on in my report.—G. K. W.

It seems at first sight an incongruity in Professor Whiting's plan that we should dig a *boating* channel through the shoal in the bay to the cut through the beach, when it is expected this cut will move eastward and leave the boating channel behind. But Professor Whiting's idea of the boating channel was to have it formed by enlarging a partial channel already existing in the shoal, and he relied upon there being a constant connection between the cut as it moved eastward and the proposed boating channel by means of a natural channel which has always existed between the beach and the inner shoal.

This inside shoal appears to have been formed by the sand brought in through the former inlets. Much of it is bare at low-water.

The channel between it and the beach is itself shallow and of irregular width, and no boat drawing more than one foot can use it throughout at low-water. I think the cutting of a channel through the shoal, even at the most favorable point, was not necessary to the success of the cut through the beach, and it might have been left till the opening through the beach was secured. As it was, the making of this cut involved, as he estimated it would, the largest portion of the expenditure. Had the money all been expended in opening the beach itself, it would have given more chance of success, although I think even then success was very uncertain.

The second point I would call attention to in Professor Whiting's plan is the width of the proposed artificial cut, which he took at 300 feet, "equal to the narrowest section of the natural passage-way between the harbor and bay." The remark following—"This is not wider than desirable for a boating channel"—indicates that some physical idea other than the want of a boating channel determined in his mind the proposed width.

The only physical condition which he states as regulating the desired width is that it must be "of such a width as shall at once secure, when opened, a stream of considerable volume."

If the channel between the bay and harbor is to determine the required dimensions of the new opening, it would seem the most natural that it should have the same sectional area. Now, the area of section at high-water, at the point between the bay and harbor where the width is 300 feet, is about 6,600 square feet, giving a mean depth of 22 feet. Judging from the accounts of former openings and the condition of the gravel and pebble bar, which our operations of the past year show must exist at the ocean end of the inlet, it does not seem probable that the mean high-water depth of the opening would exceed 4 feet. Hence the new width would be at least $\frac{6600}{4}$=1,650 feet. We knew such a shoal water-way would not give the same facility for water to flow as the narrow and deep one of the same area, so we should expect the natural opening to exceed this width, such as it was found to be by measurement, about 2,000 feet wide, when presented directly to the ocean. A less width might suffice when the inlet was presented to the current of the Muskeget Channel.

Now, if 2,000 feet is the natural width of opening presented direct to the ocean, requisite to permanence against the immediate effect of a storm, it is not improbable that any materially less artificial width would be closed "by an intervening storm or ocean swell" before it obtained its normal width.

Our operations the past year show almost conclusively that an opening through the beach sufficient to merely start the water running out, made at the time predicted by Professor Mitchell, probably will not

"create a natural outlet," unless aided by a remarkable recurrence of favorable tides, calm weather, and quiet seas.

(See report of Mr. Van Ingen, civil engineer, appended to this.)

The report of Professor Mitchell, Assistant United States Coast Survey, to the Superintendent of the United States Coast Survey, forms a part of the appendix of the report of the Massachusetts Board of Harbor Commissioners, made January, 1872. This report of Professor Mitchell's relates to both Edgartown and Nantucket Harbors, and is mainly devoted to "*physical aspects and peculiarities.*"

I will endeavor to extract from this report so much of Professor Mitchell's views as appears to me to represent the physical forces operating at Cotamy Beach, not taking them in the order presented, however, nor quoting always his exact words. He says:

Professor Whiting's repeated topographical surveys along the south side of Martha's Vineyard show that the bluffs are being continually undermined by the sea, and since the waves running before the prevailing westerly winds strike the shore diagonally, there is a tendency "of all materials to work down to the eastward"—a tendency which seems to have resulted in the choking up of all the indentations of the original shore-line, and, finally, in the formation of shoals on the border of Muskeget Channel, where the coast-wise movement is turned off by the great stream from the sound, (Nantucket Sound.)

* * * * * * *

This action of the waves to move the material of the shores in one prevailing direction is common to all shores. The motion of the waves, however, is not always in the direction of the prevailing winds. This fact is noted in many publications. An example of this is shown by the action of the waves on the north side of Long Island, N. Y., which drifts the material westward, while on the south side the motion of the drifted material is eastward, and yet the prevailing winds must be essentially the same on the two sides of the island. Another example is furnished by Lake Michigan. On the west side, south of Milwaukee, the prevailing motion is southward, and north of that place it is northward, and yet the prevailing wind must be the same. The prevailing wave motion must be influenced by the tendency which wave oscillations have to move from the deep waters as a center toward the shores. In some instances the prevailing drift, too, must be modified by the prevailing action of the littoral currents.

Professor Mitchell gives quite elaborately his view of the formation of the beach, but this is expressed somewhat differently from my understanding of the formation, and I will not quote it here, but give my own view further on. Our difference does not practically affect the question of making a new outlet through the beach.

I do not find pointed out in his report the relation existing between the motion of the beach-materials and that of all former openings in the same direction, although, I take it, one is the cause of the other. The motion of the materials of the beach being eastward, this material falls into the opening on its west side, and accumulates there, and the narrowing causes abrasion to commence on the east side of the opening to maintain its capacity. The action of the wave itself is also to abrade the chop on that side. Such action is going on everywhere along our coasts. The "proneness to close" in particular neighborhoods is, in this case, as Professor Whiting says, where it reaches "the fast land of Chappaquiddick," on its east side, which the current through the outlet cannot abrade fast enough to keep pace with the filling in on the opposite side.

Professor Mitchell says, referring to Professor Whiting's explanation of the manner in which he supposed the former opening closed:

I cannot agree with Professor Whiting in supposing that the beach has gone on accumulating till it presents a barrier difficult to overcome, because the power of the tidal

circulation seems to me out of all proportion to the obstacle. I incline rather to the impression that the outlet shifting to the eastward has, in this instance, happened to run its course, and close on the border of Muskeget Channel before any great storm had occurred to open a new pass to the westward.

Professor Whiting's explanation (see extract from his report) seems to me the correct one, of a physical result by physical causes. What follows in Professor Mitchell's report, "that the opening must gradually lose its strong tidal current as it moves eastward, and very decidedly when it reaches Muskeget Channel," seems inconsistent with his own objection to Professor Whiting's explanation, viz, "because the power of the tidal circulation seems to me out of all proportion to the obstacle."

I think Professor Mitchell much overrates the power of the tidal circulation in comparison with the other forces. The tides act alternately in opposite directions, and four times a day there is a considerable period of the tide when there is almost no current at all, and during which the forces at work closing the opening may be at the height of a paroxysm.

When I read "of the former opening closing before any great storm had occurred to open a new pass to the westward," I hoped to find some idea of how the natural forces in a great storm might make a new opening; but beyond this allusion to such a desired consummation, there is nothing said in the report. There is a view expressed on this point by Professor Whiting in Appendix 13 of the Annual Report of the United States Coast Survey for 1856, which I will refer to further on, when giving my view of this matter.

As before said, one of the most important parts of this subject relates to the tides, for on the tidal differences on the opposite sides of the beach, mainly rests the hope of making an artifical opening through it.

Professor Mitchell says:

> There approach our coast from the ocean two oscillations of the tide, which meet, (as you [Professor Peirce] express it,) and *'form their node'* southward of Nantucket Island. From Great Point, Nantucket, along the outer coast of America* northward, high-water occurs at or shortly before the transit of the moon, while from Smith's Point, Nantucket, along the outer coast, to the southwest, high-water occurs four or five hours earlier.
>
> * * * * * * * *
>
> These two oscillations entering the sound, (Nantucket,) the one by Gay Head and by Muskeget Channel, and the other by the eastern entrance, give very complicated tides between Tarpaulin Cove and Tuckernuck.
>
> In the small tides of Holmes Hole, Muskeget Channel, and Wewesder, (south side of Nantucket,) there are sometimes four high-tides in one day distinctly given by gauging. But I must not enter upon details that would complicate the conception, and I would remark, by the way of preparing the reader to trust my calculations, given below, that the phenomena present really no complication when simultaneously observed from point to point.

I regret very much that Professor Mitchell did not present us a fuller view of these tidal phenomena and the various *fluctuations* to which they are liable, which presentation I, who am so little prepared, shall have to make from the study of the United States Coast Survey Reports.

My object is to give a general idea of the tides and currents and the causes of their variation, so that it will be apparent that although observations extended over long periods may secure mean results, yet that the mean will furnish us no reliable ground for practical operations.

* It will appear, further on, that the same tidal wave reaches the shores of Nova Scotia as does at Block Island, and that this remark about the tides of the coast of America is not true at that point, nor, strictly speaking, does the reapproach from the ocean two oscillations. They both come from the same, but one is modified by the shores.—G. K. W.

In the Annual Report of the United States Coast Survey for 1857, p. 350, Professor Mitchell says:

The study of tides and currents must be regarded in a twofold relation: first, as affording the means of constructing prediction tables for immediate use in navigation; second, as an inquiry into a class of agencies whose ceaseless activities are gradually altering the configuration of our harbors and sea-coasts, here cutting away headlands, there stretching out hooks, destroying at one point and building at another. We are called upon not only to exhibit the daily and hourly conditions of these great elements, but to ascertain their offices, their modes of operation, and their effect.

In Professor Mitchell's pamphlet on tides and tidal phenomena, published by the Bureau of Navigation of the Navy Department, Scientific Paper No. 2, he introduces the subject thus:

Tidal phenomena present themselves to the observer under two aspects: as alternate elevations and depressions of the sea, and as recurrent inflows and outflows of streams.

The word *tide* in common usage is applied without distinction to both the vertical and the horizontal motion of the sea, and much confusion has arisen among navigators from the double application of this term.

Careful writers of modern times, however, use the word *tide* in strict reference to the *changes of elevation*, while they distinguish the recurrent streams as *tidal currents* or *tidal drifts*. With regard to the words *ebb* and *flood* no distinction of application has been observed.

A discussion by Prof. A. D. Bache, based upon actual observations of the currents and rise and fall of—

The complicated system of tides in Nantucket and Martha's Vineyard, and the sea outside of the islands giving names to the sounds,

was commenced in the Annual Report of the United States Coast Survey for 1854, p. 36. It continues:

This region forms the dividing space between the tidal establishments of eight hours and of twelve hours or more, properly the cotidal hours of XII and XV.*

In Professor Mitchell's report in Annual Report for 1856, p. 263, we read:

The western or XII-hour wave as observed at the extremity of our field, (Block Island,) is similar in every respect to the general tide-wave observed along the coast between this point and Georgia. Its half-monthly irregularities in heights is almost identical with that observed at Old Point Comfort, Virginia; even the individual waves compare well at these two places. The eastern or XV-hour wave at the other extremity of our field, (Monomoy,) is far from being similar to the tides of the coast to the northward; its individual tides differ from those of Boston, and its large irregularities would seem not even to be multiples of those observed at that place.

The mean rise and fall of this wave at Monomoy is about 3 feet.

The eastern or XV-hour wave is then evidently affected by the western wave, and in order to find the simpler form of the XV-hour tide-wave we must go farther north.

The report of Professor Bache (Annual Report of the Coast Survey for 1857, Appendix No. 33, p. 342) gives along with the determination of the tide, made under his own superintendence, a few made by Captain Shortland, R. N., and Admiral Bayfield, R. N., extending our partial knowledge of the tides to the northeast as far as Cape Breton Island. It seems probable from the chart accompanying this annual report that it is the same ocean oscillation which reaches our coast in its simple form almost simultaneously south of Martha's Vineyard Island and at Cape Breton Island. From this latter point southwestward, as the wave moves

* There is an apparent discrepancy here in the establishments of 8 hours and 12 hours, and the cotidal hours of 12 hours and 15 hours, but the probable explanation is that the establishment time refers to local differences between Gay Head and Monomoy, while the cotidal hours refer to the lines drawn through points when the tide waves are not locally affected.—G. K. W.

shoreward into the great indentation along the coast of Maine, it meets with retardation in time and receives an augmentation of heights, and thus may be generated the modified tide reaching as far south as Nantucket.*

This modified tide-wave, however, undergoes other modifications as it approaches the simple wave south of it, and we cannot take the tide-wave at Monomoy as indicating the form and extent of the northern or XV-hour tidal derivation. For the purpose of this report it may be near enough to take the tide-wave as it appears at Provincetown, Cape Cod, where the mean rise is about 9 feet, (and does not change materially from this along the coast of Maine,) as representing this northeastern wave.

Therefore I assume that the 9 feet at Cape Cod, and 3 feet at Block Island, represent the extent of the oscillations of these waves where uninfluenced directly by each other.

The following other differences between these two tide-waves is stated by Professor Mitchell, (Annual Report 1856, p. 253:)

> Though the mean rise and fall of the western wave is less, the half-monthly changes in magnitude are much greater with this than the eastern wave. All the other irregularities differ also in degree. Thus occurs the alternate predominance of the tide-waves at their point of meeting.

The point of meeting above referred to I take to be simply the meeting of the oscillations only.

The other phenomena, *the tidal currents*, produced by these oscillations, occupy the whole interval between Monomoy and Gay Head in their equalization, and each predominates through all the space, to a more or less degree, twice a day. The real meeting and neutralization of these two tide-waves requires the whole space in the sounds, straits, and ocean between Cape Cod and Gay Head.

The want of synchronism in these two tides is such that the high part of one falls partly into the hollow of the other, and thus everywhere between the places where each is independent, the resulting tide is less than it would have been if the dominant tide prevailed.

The width of the passage between Monomoy Point and Nantucket Island, through which the larger tide enters, is nearly as great as the combined widths of the Muskeget Channel and the Vineyard Sound Channel, through which the other enters, and its depth is on an average greater. The extreme effect of the western tide in different parts of the sound must be less than that of the other, its magnitude at any point depending upon the proximity of the inlets filled by this western wave.

Professor Mitchell says, page 262, Annual Report, 1856:

> It is ascertained from lines of leveling connecting the tidal stations that the mean level is identical for the two systems; that is, the tide-waves throughout this region rise and fall above and below a common plane.

Though this is not doubted, for long periods the observations made by us, between October 16, and November 1, inclusive, and on November 6 and 7, mainly during the day-time, which favored the greater tide on the inside of the bay, gave on the average the low-tide in the ocean, 0.2 foot above that in the bay, and the mean level in the ocean, 0.5 above the mean level in the bay.

On October 26 the low-tide in the bay was 1.0 foot lower than the

* If this idea is correct it seems hardly proper to say, as I have quoted from Professor Mitchell, "that there approaches our coast from the ocean two oscillations of the tide," and these appear to be two derivations of the same ocean-oscillations or tide waves.—G. K. W.

low-tide outside, and the high-tide in the ocean 2 feet above the high-tide in the bay.

It seems, therefore, probable that the unequal action of the two tides in filling and emptying Nantucket Sound under varying conditions of seasons, preserves for considerable periods the mean level of Nantucket Sound different from the mean level of the ocean. Not only do the relative mean levels (which determine the head of water) change, but the absolute mean level changes as well as its mean slope. This, though not materially affecting the flow of water in the large natural channels, is of vital importance to the flow through an artificial opening of little depth and width.

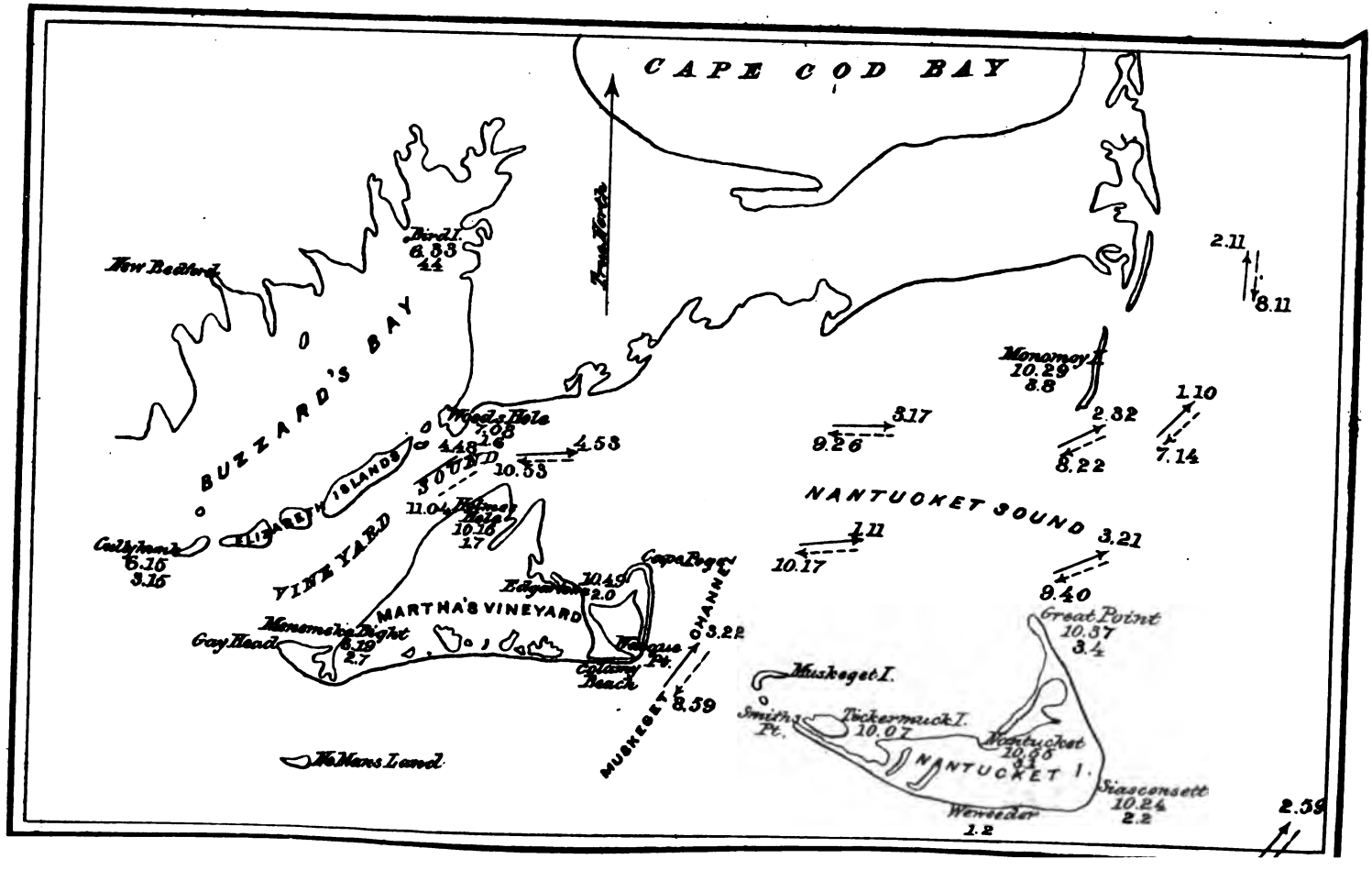
The winds, which all along our coast have a great influence on the tides, here produce extraordinary modifications both in the periodical and daily mean level. This is true not only of the prevailing winds of a season, but of their abnormal changes. Easterly winds increase the inflow of water from the eastern tides greatly, and generally increase both the eastern and western tides, while westerly winds diminish the ocean-tides and favor the outflow through both the eastern and Muskeget inlets. Navigators assert that the irregularities are so great that sometimes the ordinary daily alternations of east and west tides in Nantucket Sound do not take place, the current remaining continuous in one direction.

The tidal *currents* which these two tidal oscillations occasion are among the most complex features of this region. For the purpose of presenting a general idea of them, the accompanying map, extending from Monomoy to Cuttyhunk, has been prepared from the United States Coast Survey Reports, to exhibit the average conditions during the period of a single oscillation of the tide-wave south of Martha's Vineyard. The hours are numbered from 1 to 12, beginning with the first hour of the rising tide. The time at which high water occurs at different points is noted on the map, and the mean rise near it, in feet. Arrow-heads at different places show the changes of direction of tidal currents, and the time of change to this direction is noted with each arrow. In this connection consider also the profiles of the tidal changes given in Chapter II.

I will now describe the ordinary tidal currents in the interfering and tranquilizing district between Gay Head and Monomoy, corresponding to the changes of level of the water-surface inside and outside of Cotamy Bay. My object is to present these currents to the mind so as to show their practical bearing upon the engineering question. I shall therefore use common terms and not the scientific ones, which involve conceptions not easy to be realized except by those familiar with the scientific study of tidal phenomena.

Let us begin with the conditions existing at the time of low-water in the ocean south of Cotamy Bay. This occurs when the moon is about one and a half hours past the meridian. The tide in Nantucket Sound and Cotamy Bay has now been falling about two hours, but is still almost at the greatest difference of level above the ocean-surface. The current is now running out through the Muskeget Channel and Vineyard Sound, but still running in at Monomoy, showing that the tide just northeast of Monomoy, when it first begins to fall, discharges its waters into Nantucket Sound and out through the other channels.

After the ocean-tide south of Cotamy Bay has risen about one hour the ocean northeast of Monomoy has fallen so much that the current begins to run out at Monomoy, and Nantucket Sound is emptying through all its outlets. This state of things continues till the beginning of the fourth hour of the rising tide outside of Cotamy Bay. At


CAPE COD BAY
True North
New Bedford
Bird I.
6.33
4.4
BUZZARD'S BAY
Woods Hole
7.08
4.48
4.53
10.53
ELIZABETH ISLANDS
VINEYARD SOUND
11.04
Holmes Hole
10.16
1.7
Cuttyhunk
6.15
3.15
MARTHA'S VINEYARD
Menemsha Bight
6.19
2.7
Gay Head
Edgartown
10.49
2.0
Cape Poge
Wasque Pt.
Colony Beach
MUSKEGET CHANNEL
3.22
8.59
No Mans Land
Monomoy I.
10.29
3.8
2.11
8.11
1.10
7.14
2.32
8.22
3.17
9.26
NANTUCKET SOUND
1.11
10.17
3.21
9.40
Great Point
10.37
3.4
Muskeget I.
Smiths Pt.
Tickermuck I.
10.07
Nantucket
10.55
3.1
NANTUCKET I.
Siasconsett
10.24
2.2
Weweeder
1.2
2.59

this time the ocean-level south of the sound has become higher than in the east part of the sound and the current passes into the sound from the Muskeget Channel and flows directly in toward the Monomoy entrance. This influx of water at the Muskeget Channel slightly retards the fall of the water in the sound, and it also slightly retards the rise of the ocean-tide outside of Cotamy Beach. At this time the Muskeget Channel and the eastern entrance may be regarded as a continuous strait conveying the water of the southern rising-ocean tide-wave to the falling northeastern one. At about the end of the fourth hour it is low-water in Nantucket Sound and Cotamy Bay, and soon after the current begins to run into Nantucket Sound through the Vineyard Sound. When this takes place all the main currents in Nantucket Sound become easterly currents inward at the Muskeget and Vineyard entrances and outward at Monomoy. The rise of the tide in Nantucket Sound and Cotamy Bay, due to the eastern tide-wave, begins about the fourth hour.

The difference of level between inside and outside of Cotamy Beach has now reached its maximum, though it decreases but little for several hours thereafter, the two tides rising apace.

At the end of the sixth hour the ocean tide is giving high-water along the south shore, and, its level being still considerably above that of Nantucket Sound, the current continues running in through Vineyard Sound and Muskeget Channel and out past Monomoy. The southern tide now begins to fall, and the currents from Vineyard Sound and Muskeget, with diminishing heads, lose part of their velocity, and the water not running in through these passages as rapidly as before, while it is still running out past Monomoy, the level of the sound stops rising, or even falls a few inches. The Cotamy Bay tide during the seventh hour of the falling tide outside is over half up, and remains at about this level until the beginning of the ninth hour. Then the tide from the east rushes so rapidly in as, with the assistance of the Vineyard Sound and Muskeget currents, to force up the level of the whole sound.

The water at this time (the beginning of the ninth hour) is running in from all directions. By the end of the ninth hour the level of the sound is so much above that of the ocean, that the water begins to flow out through Muskeget Channel. This regimen continues until a little after the beginning of the eleventh hour, or 2 to 3 hours after the Monomoy current has begun to flow in, when high-water occurs at Monomoy, Edgartown, and other points on the sound. It will be noticed that the first part of the Nantucket Sound rise comes from the first ocean tide, though the top is due to the superimposing of the Monomoy tide on that of the other. Soon after this high-water has been reached, or at the end of the eleventh hour, the water runs *out* of Vineyard Sound, still running in past Monomoy, but not with sufficient velocity to make the supply equal to the discharge through the other passages. It is now a westerly current in all the channels. This continues until the same conditions with which we started are reached.

The bearing of the foregoing description of the action of the currents on the question of making an opening through the beach is mainly this: to make us see that the ocean tidal wave south of the beach is very little affected in its form by the other wave, and that it must be tolerably symmetrical, and have its mean level approximately half way between high and low water, while the rise inside of the bay is much affected when about half up by the falling of the tide outside.

The mean range of the tide given in the United States Coast Survey

reports for the two tides is 2 feet at Edgartown and 2.7 feet outside the beach.

A recent letter from Mr. Mitchell states that for long periods he regards the mean range the same for both tides, viz, 2.4.

From our observations in October, 1873, the mean range outside was much greater than inside, and the mean level outside above that inside. Some days the conditions favoring an inflow were four times as great as those favoring an outflow. These few observations accord with Professor Mitchell's statement, that all accounts of former openings showed a greater inflow than outflow. For this he gives an explanation in the condition of the bar at the ocean side of the former openings.

I do not know the data on which Professor Mitchell now concludes that the two mean levels are the same, but, unless it rests upon a length and accuracy of observation precluding a doubt, I should be inclined to question it.

The following data in regard to the tides and their bearing upon the proposed work is taken entire from Professor Mitchell's report:

Edgartown Harbor.—Upon the map which accompanies this report I have drawn profiles of the tidal curves for Cotamy inside and outside, so that one with his eye may see how sharp the contrasts of the tides appear on the two sides of this beach, and how much the relative levels differ. Not trusting any single day's work, however, but going back to the whole series, I give below a table of average conditions.

TIME.

Cotamy Bay, at the same level as the sea outside, (before moon's transit) ..	2 h. 32 m.
High-water in Cotamy Bay, (after moon's transit)	0 h. 28 m.
Greatest height of Cotamy Bay above the sea outside, (after moon's transit,).	0 h. 40 m.
Cotamy Bay again at same level as the sea outside, (after moon's transit)..	4 h. 40 m.

DIFFERENCE OF LEVEL.

Maximum height of Cotamy Bay above the sea, (after the larger high-water).	1.36 feet.
Maximum height of Cotamy Bay above the sea outside during a northeast gale of ordinary violence.....	1.83 feet.

The times of the preceding table, which are counted from the moon's transit, (*i. e.*, from her southing or northing,) are subject to variations of about 40 minutes either way. It will be safe, however, to provide for throwing open the canal two hours before the time of transit given in the almanac.

Those differences of level only are given in our table which favor the outflow, and those only which follow after the *larger* of the two tides which occur on the same day. Care should be taken to select this larger tide, and this may be done by referring to the heights at Boston, given in the tide-tables of the Coast Survey for every day of the year. The differences of height do not increase very much from neaps to springs, but as the opening is to be made (according to our presumption) about the time of high-water, there will be a saving of labor by selecting a period of high-tides. There will also be a decided advantage in selecting a period of strong winds from north to east, but winds from the opposite quadrant will prove very unfavorable. During the period when the surface of Cotamy Bay is above that of the ocean, (*i. e.*, from 2 h. 32 m. before till 4 h. 40 m. after the transit,) the current runs southward through Muskeget Channel, and sometimes feebly to the westward along the outside shore of Cotamy Beach, but the prevailing stream along this shore sets to the eastward, within the Wasque Shoal.

The soundings in the harbor of Edgartown, given upon the accompanying chart, executed by Mr. Marindin, differ from those which appear upon the chart of Lieut. Chas. H. Davis (dated 1846) in three localities of limited extent:

1st. One foot more water can now be brought into the town basin over the bar.

2d. The apron of sand within Chappaquiddick Point has extended so as to reduce the depth all the way across the channel and impair the holding-ground. The cross-section most encroached upon has lost about twenty-five per centum of its area.

3d. The increase of the bulk-head or shoal in the broadest portion of Cotamy Bay has occurred, and amounts to nearly 1,000,000 cubic yards.

From inquiry among the citizens of Edgartown, I learned that the increase of water over the bar had not been noticed by them, so I conclude that it may be nothing new, but a gradual change of past years.

It was quite otherwise with the apron of Chappaquiddick Point, which had excited attention by its recent advances. The shoal in Cotamy Bay has undergone so many modifications of form within the memories of pilots and boatmen that their testimony was uncertain. Until we can have still another survey, we must infer that the two years' closure of the beach has not affected the bar or bay, but has conduced to the shoaling of the main channel, and has greatly reduced its width at one point. What this change portends I do not dare predict, but I agree with the good people of Edgartown in thinking that something ought to be done to stop it forthwith.

OPINIONS OF THE ADVISORY COUNCIL.

In the appendix to the report of the board of harbor commissioners is also the report of the United States advisory council, consisting of Admiral C. H. Davis, U. S. N., Prof. Benjamin Pierce, superintendent United States Coast Survey, and Prof. Henry Mitchell, United States Coast Survey, who approved the project. The following quotation expresses their confidence in its success:

An acquaintance with the hydrography of the neighborhood, at times very intimate, during a quarter of a century, discovers to us no fundamental changes in the physical conditions, and we believe that with the artificial opening of the inlet nature will at once respond to the efforts of the engineer, resume her good offices, restore the former regimen of the currents, and maintain perhaps for years all the advantages that have distinguished this harbor. That the inlet will repeat the history of those which have before existed, shifting eastward and ultimately closing, we do not doubt, but the remedy may always be repeated, and will never be expensive.

The next step in the prosecution of this undertaking was a memorial by the commissioners to Congress praying for an appropriation. This is printed with their report. In compliance with a resolution of the House of Representatives of April 7th, 1872, a survey was made by George Thom, lieutenant-colonel United States Engineers, under instructions from the Chief of Engineers. His report is printed in full in House Ex. Doc. No. 297, 42d Congress, 1st session, and partly reprinted in the annual report of the Chief of Engineers for 1872. From the full report I quote:

In order to ascertain the character and quantity of the material to be excavated, and to determine the most advisable location of the proposed opening through the south beach, near its western extremity, as well as to ascertain what changes, if any, have taken place in the beach since the survey was made last season, (changes which were supposed to have been caused by the extraordinary storm of the 15th November last,) a resurvey has been made with special reference to those points.

* * * * * * *

By comparing this map with the map accompanying the memorial of the harbor commissioners, it will be seen that the changes which have occurred along the south beach where surveyed have been unimportant.

The channel* which, in my opinion, is the most feasible and desirable to have opened is shaded red in the accompanying map. This would guide the tidal currents in the shortest and most direct course from Cotamy Point to the ocean, and would not, like the crooked channel west of it, be liable to be closed by eddies formed by the ocean swells, and, as shown by the survey, the quantity of excavation required would be smaller than for a channel at any other place to the westward of it. Moreover, in passing the south beach it would sooner enter the deep water of the ocean, without encountering the breakers indicated on the harbor commissioners' map.†

Estimates have been made for both the eastern and western channels, (shown in the drawing) and for widths of 100, 200, and 300 feet, (allowing for a side slope of 45°,) and to a depth of 4 feet at mean low-water, all that is required either for the scour of tidal currents or for the passage of the small boats, such as are generally used by the fishermen and the pilots at that place.

The exposure of this beach to the ocean storms, and the consequent liability to diffi-

* This is almost exactly the channel we worked out.—G. K. W.

† Our observations show that in heavy storms there is an uninterrupted line of breakers all along the shore, not unusually great in magnitude, but following one after another so quickly that no boat that was small enough to not strike the bottom could live in them at all.—G. K. W.

culties and interruptions in opening a channel through it, renders it advisable, in my opinion, to open by excavation as much of the channel as practicable, so as to favor as much as possible the action of the tidal currents in their completion of the work. The estimates have, therefore, been made to include the excavation by dredging of all the material (coarse sand) to a depth of 4 feet below mean low-water southward to within 50 feet of the high-water line of the ocean, all above high-water (on the beach) to be removed (at a less expense) by barrows or carts.

In the report of Mr. H. L. Whiting which accompanies the memorial of the harbor commissioners above referred to, he recommends that the width of the new inlet should be about 300 feet, which "is about equal to the narrowest section of the natural passage-way between the harbor and bay, and is not wider than is desirable for a beating channel," in which I fully concur with him. But as it is highly important for the preservation of this harbor that an opening should be made this season, so that the harbor may derive immediate benefit from the scour of the tidal currents, and as there may be also some doubt as to the complete success of this undertaking, it is respectfully recommended that the proposed channel should be first opened to a width of 150 feet, only, to be afterward increased to a width of 300 feet for purposes of navigation. It is however, more than probable that in once making an opening to a width of 150 feet as proposed, the action of the tidal currents (as shown by Professor Mitchell) would operate to singular advantage, and would increase the channel in part, if not fully, to the desired width of 300 feet.

An estimate is, therefore, made for this season for a channel 150 feet in width only, which is as follows:

34,000 cubic yards excavation by dredging, at 50 cents	$17,000
10,000 cubic yards excavation by dredging, with carts and barrows, at 30 cents	3,000
Adding for contingencies, say	2,000
	22,000

The changes in Professor Whiting's plan and estimate made by General Thom were in reducing the width from 300 feet to 150 feet, and in designing to dig through the beach down to 4 feet below mean low-water instead of to the level of mean high-water, a difference of about 7 feet.

The line selected by General Thom did not follow the natural channel-way which Professor Whiting suggested, but was a direct one from the point on the west side of Cotamy Bay to the ocean. The total amount of material to be excavated was estimated by Professor Whiting at 55,000 cubic yards, and by General Thom, in his project, 44,000.

The act of Congress approved June 11, 1872, appropriated $20,000, having omitted the item of $2,000 for contingencies.

CHAPTER II.

ACCOUNT OF THE OPERATIONS TO CARRY OUT THE PLAN OF IMPROVEMENT RECOMMENDED, WITH THE RESULTS AND OBSERVATIONS.

On the commencement of the fiscal year, July 1, 1872, this work was placed under my charge. I advertised for proposals to make excavations, and the lowest offer received was 40 cents a cubic yard. This I thought too large a price, and did not enter into a contract; but I was still further influenced by the circumstance that other work beside the excavation would probably have to be done, the exact amount of which could not bef oreseen, and which a contract would not leave me with discretionary power to execute. Principal of all the other work that I considered important, was the building of a jetty out on the ocean side of the beach to the west of the proposed cut, to interrupt the progress of the sand along the shore and prevent it filling up the cut. I was unable to make any satisfactory arrangement of the work that year.

In the beginning of the season of 1873, I submitted a plan of opera-

tions to do the work immediately under my own directions, by hiring dredges, tugs, teams, and men by the day, as I might find best, leaving me at liberty to change anything, as experience or necessity compelled me. This course was approved by the Chief of Engineers. The work was in progress on August 30, and was reported upon by me in general terms at that date. See Annual Report of Chief of Engineers for 1873, p. 949. I stated there that at that time I saw no occasion to change the general features of General Thom's plan. The dredging was begun, almost exactly on the line he recommended, about July 21, by an Osgood dredge, to make the channel through the shoal inside of the beach. Here the depth was too little to allow scows to be used, so a first cut had to be made by the dredge, throwing the material over on the west side. Afterward scows were introduced, and this cut was widened out to 60 feet, and in some places more.

A great deal of extra trouble and expense in making this channel arose from the washing of sand into it from the sides during storms and by the tidal currents, which caused sand-bars to form along its course. This channel we had to make 6 to 7 feet deep at mean low-water. I now think that all the money spent on this channel, about $12,000, might have been saved by selecting a place for opening the beach about half a mile more to the eastward, near where the opening formed in 1856. There there is a deep place between the inside shoal and the beach, which would have served as a dumping-place for all the sand removed from the beach, which would have enabled us to dispense with the tug. With the means thus saved we could have commenced our cut at once at the beach, with a full width of 100 feet from the outset, for in this width the dredge could work obliquely at the beach, with scows on the outside of her, and not require any prepared way. As it was, having adopted a plan which compelled us to cut a channel through the shoal, we had not means enough to make more than a cut 60 feet wide (two widths of the dredge-boat) through the beach. Since the dredge, working end in, could not employ scows until one cut was made to float them in, we employed teams with scrapers to remove the sand back from the sides of the cut down to low-water. The dredge then made a cut through this by throwing the material over to the side, from which place it was removed by the teams and scrapers. The second cut was made by the dredge, dropping the material into dump-scows, which were towed away by the tugs. This is but a general description of the work; the details of it are given in the accompanying report of Mr. Van Ingen, who assisted me in the charge of the work.

During its progress I found that we had nothing to apprehend from the drifting of the sand by the winds. The project of building a jetty on the west side of the cut had to be abandoned for want of means. It was evident that it must be a very considerable work to have any good result. It was the important aid that the channel through the inside shoal would give in building this jetty that made me retain for it so important a place in the project, for I do not consider it had any value in securing the opening through the beach, and as far as a boating-channel is concerned, it would have been just as well to leave that alone till the opening was secured. The temporary wharf built was also intended for use in making the jetty, and so was a portable railway-track and cars, which I borrowed from another work.

The difficulties and delays we experienced threw us back considerably in time, and we were not ready to take advantage of some remarkably high bay tides which occurred in the first part of October, during a northeast gale.

When we had nearly got our cut through the beach, we came upon a

marsh sod, about 1 foot thick, underlying the sand and being about at the mean ocean level. This sod, it is well known, resists the abrading action of powerful currents, and we therefore carried our excavation seaward of the main beach entirely through it, and until we struck the cordon of gravel and pebbles which lie along the ocean shore just below low-water. This gravel and pebbles, we afterward had reason to think, had an important influence in preventing the current from deepening the water-way, both in our attempts to open the beach, and in the natural openings which have heretofore existed, and it caused us some apprehension from the outset of the undertaking as soon as we discovered it, for it was not mentioned in the former reports.

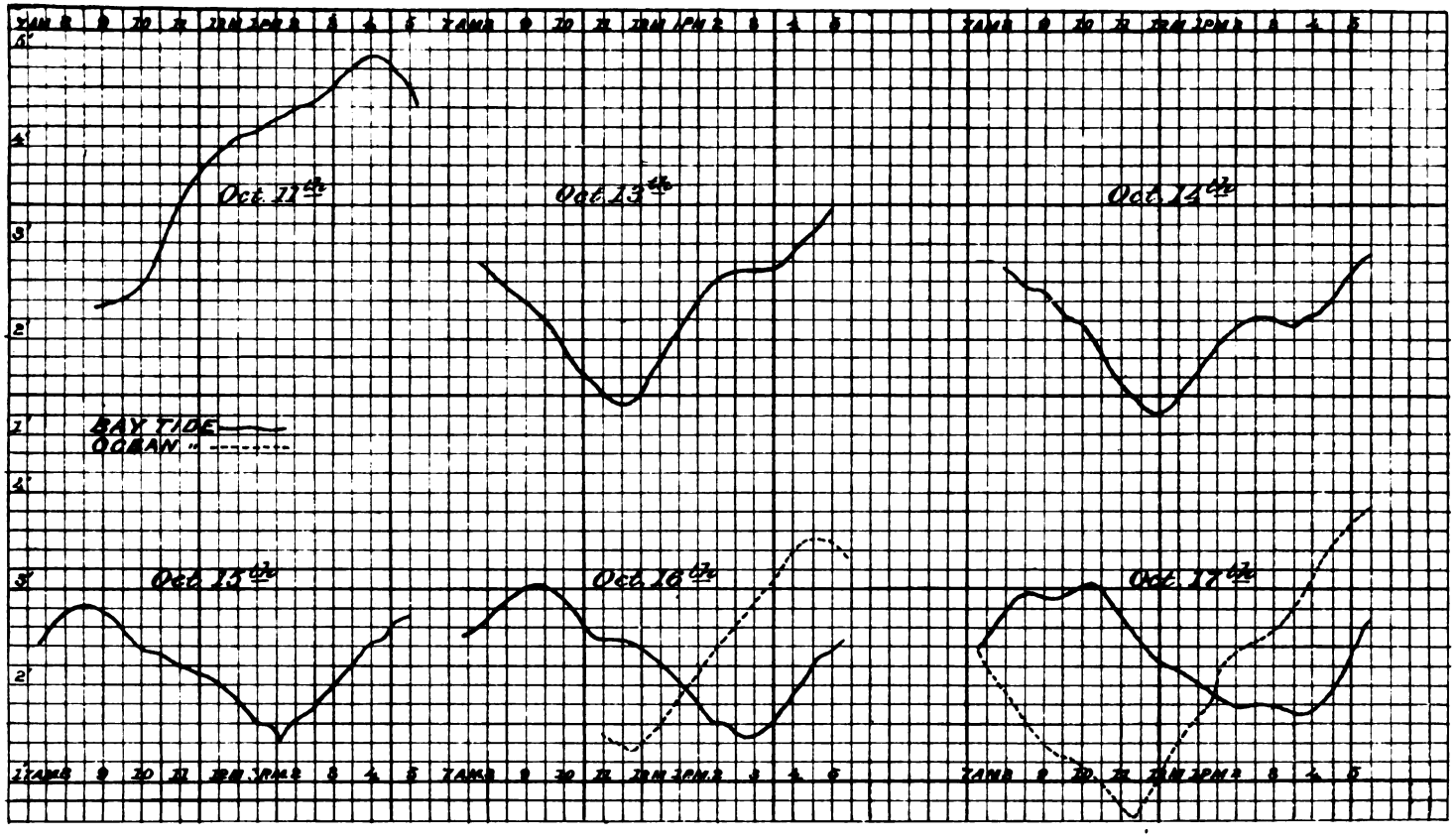
But another cause of the failure which we met with became very obvious toward the termination of our work, and that was the considerable greater elevation of the level of the ocean than of the bay inside. For some fourteen days of simultaneous observations, generally in the day-tides, which favored the outflow, we found that the mean level outside was above the mean level inside, and that the mean low-water outside was above the low-water inside. The inside tide did not give as great head as the outside tide, nor did it last nearly as long. For some tides, at the least estimate, there would have been four times as much water running into an opening, if made, as would have run out.

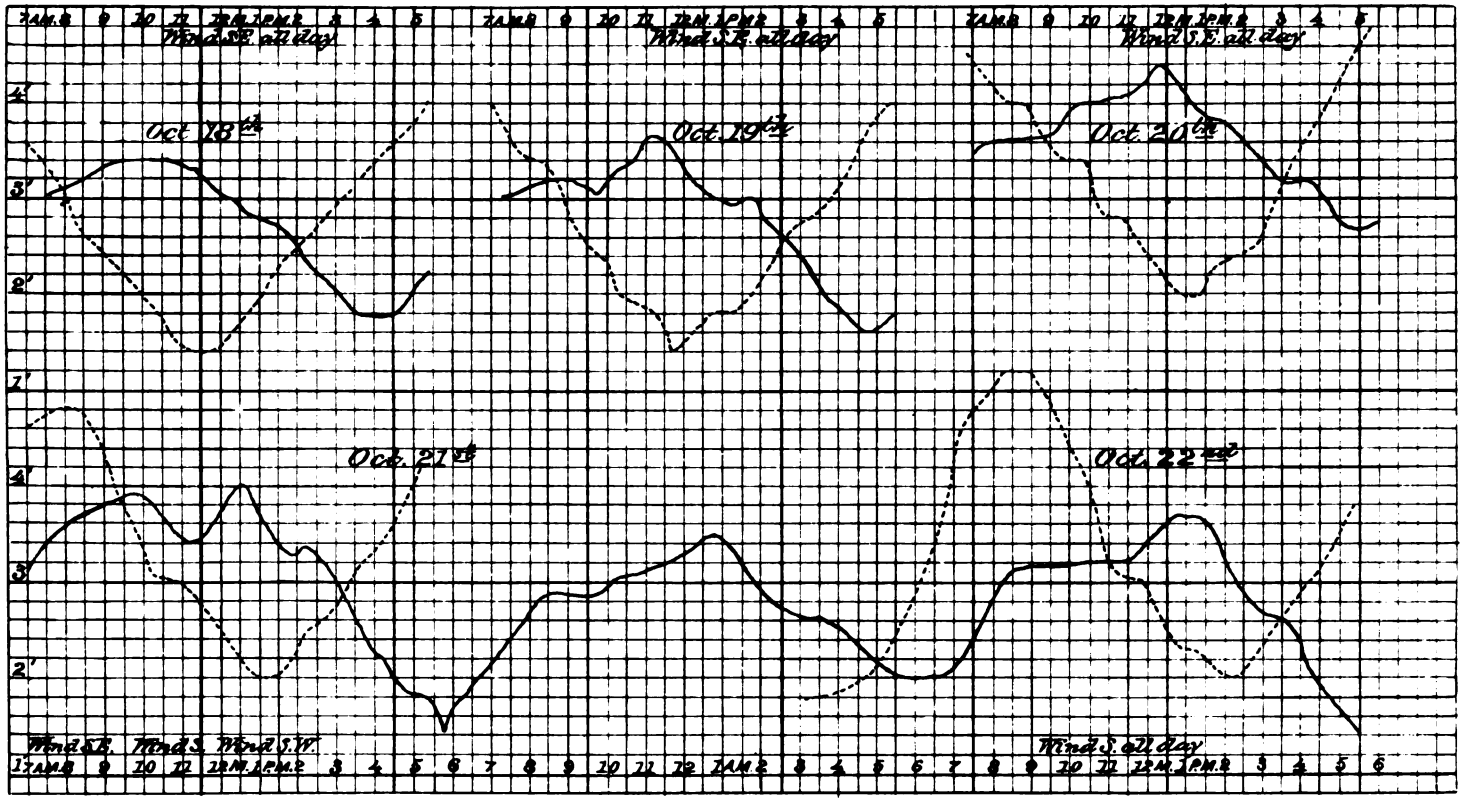
During the earlier part of our operations observations on the tides were not kept by us. The great importance of the tides, however, is well illustrated by those we did take between October 11 and November 6, and are presented on the next four pages. They show the fluctuating nature of these tides very well.

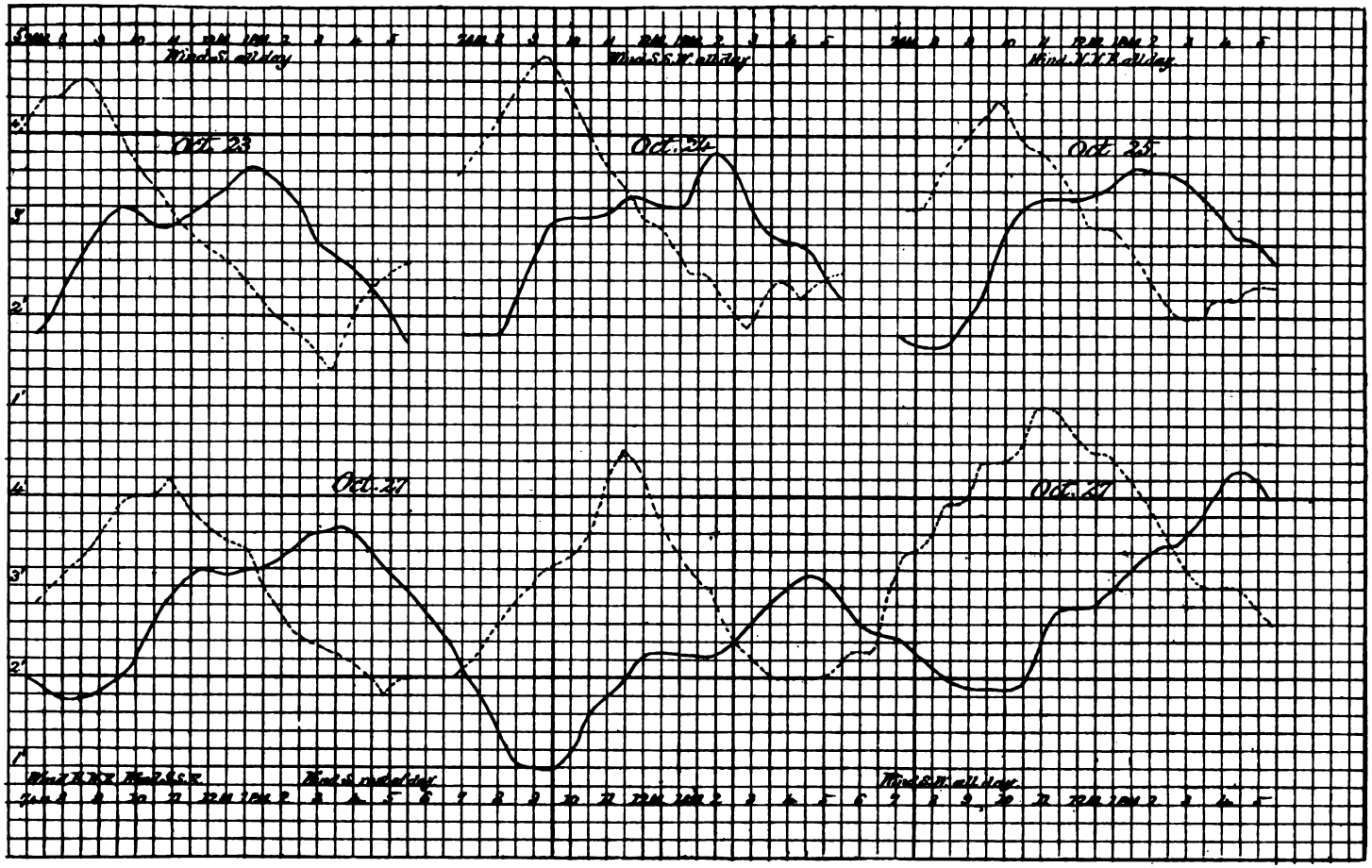
On the page succeeding these is given the average tidal curve from Professor Mitchell's report, and along with it the average of the day-tides for five days, being for the day when the ocean broke into the opening and the four preceding ones. On these diagrams the vertical sides of the small squares represent two-tenths of a foot, and the horizontal sides half hours. The full line is the bay-tide, the broken one the ocean-tide.

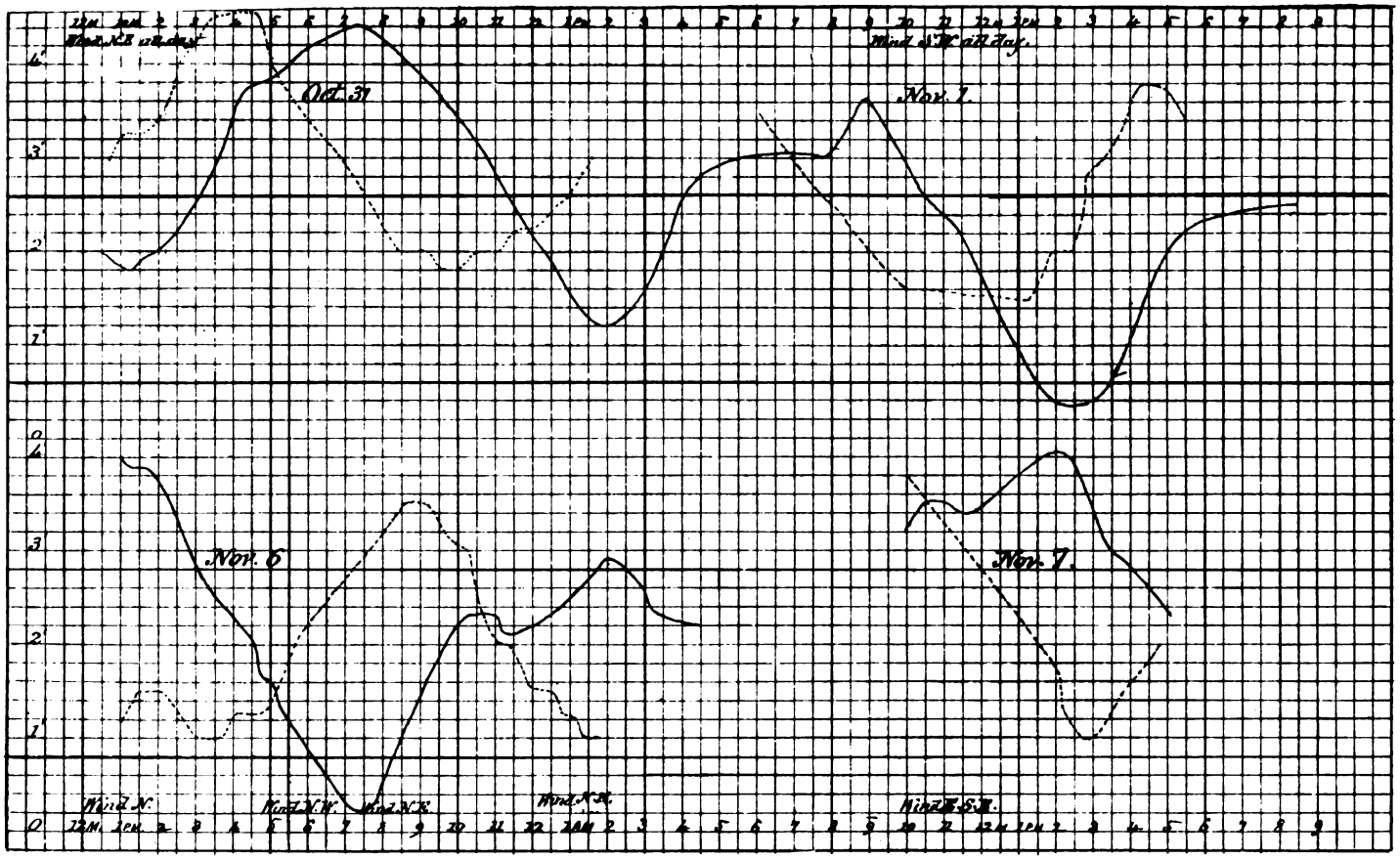
Working away with the greatest diligence, we reached such a stage that we could open the beach at midnight October 26 and 27. We had now gone so far through the beach that only a temporary barrier could be erected against a storm. All day on the 26th the sea was calm and the weather beautiful, and had been so for two or three days previous, the barometer remaining high and stationary. There were indications that a storm was brewing, and the high cirrus clouds took a northeast and southwest direction. We were too far away and isolated to obtain any information from the signal-reports. It was now the season for northerly winds, as shown by Professor Coffin's wind diagrams, in his essay on the winds of the northern hemisphere, (copied at end of this chapter,) and, judging by the indications, we had every reason to hope that if the storm did come it would be from the northeast, which would favor us with a large tide. The period of very highest tides predicted in the tide-table was on the 7th and 8th of October, but we were now at the next period of high tides, as shown by these tables.

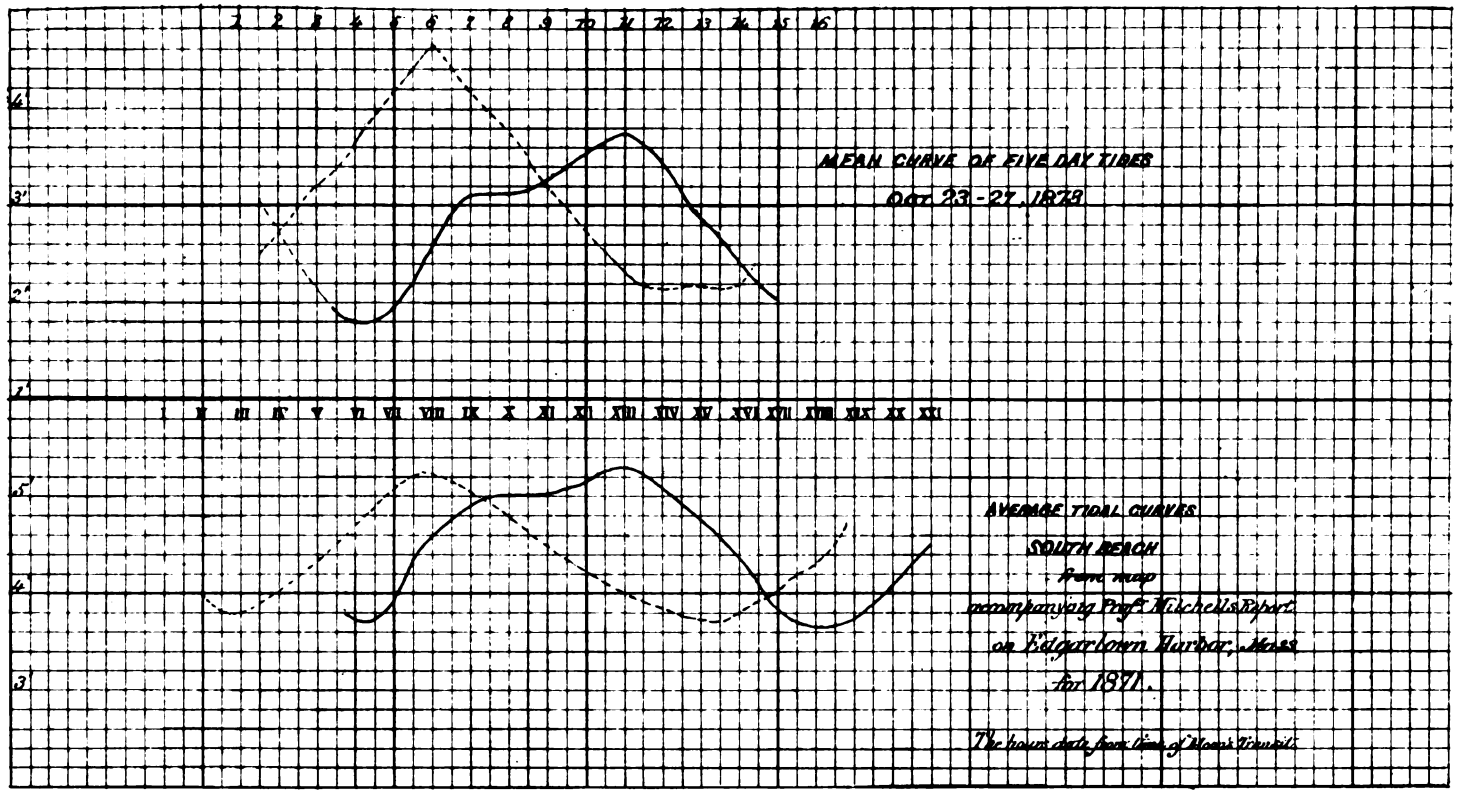
During the 26th numbers of people visited the scene of operations, and I had a chance to converse with the most experienced of those who had worked upon the beach at other places to open the fresh-water ponds. None of them professed any knowledge that would have altered what had been done at the site selected. Nearly all the people favored making the attempt farther to the east, but what was done at the place *selected they* appeared satisfied with. The remarkable smoothness of


Oct. 11th
Oct. 13th
Oct. 14th
BAY TIDE
OCEAN
Oct. 15th
Oct. 16th
Oct. 17th


Wind S.E. all day
Oct 18th
Wind S.E. all day
Oct 19th
Wind S.E. all day
Oct 20th
Oct 21st
Oct 22nd
Wind S.E.
Wind S.
Wind S.W.
Wind S. all day
4'
3'
2'
1'
4
3
2'
7 AM 8 9 10 11 12 M. 1 PM 2 3 4 5 6 7 8 9 10 11 12 AM 2 3 4 5 6 7 8 9 10 11 12 M. 1 P.M. 2 3 4 5 6


Wind S. all day
Oct. 23
Wind S.S.W. all day
Oct. 26
Wind N.N.W. all day
Oct. 25
Oct. 27
Oct. 27
Wind S.S.W.
Wind S. all day
Wind S.W. all day


Oct. 31
Nov. 1.
Nov. 6
Nov. 7.


MEAN CURVE OF FIVE DAY TIDES
OCT. 23 - 27, 1879
AVERAGE TIDAL CURVES
SOUTH BEACH
from map
accompanying Prof. Mitchell's Report
on Edgartown Harbor, Mass
for 1871.
The hours date from Noon of Mean Transit.

the sea, which every one regarded as an important element of success, was all that could be desired. There seemed every reason to expect that now, if ever, nature would "respond to the effort of the engineer."

As the day declined a light wind which was blowing from the east slowly swung round toward the south, and after sunset gradually increased, so that by midnight, when we expected to throw down our barrier, and let the high tide of the bay out into the ocean, the waves were quite high under the influence of a brisk wind from a point a little west of south. The most unfavorable bay-tide accompanied this that we had yet witnessed. The water in the bay did not at any time exceed 1.1 feet above the level outside, and the time it was above only amounted to about four hours. To open the beach at such a time was folly, so I directed it to be strengthened against the waves, and all the rest of the night as many men as could work banked up the sand across the cut, and interspersed the layers of sand with layers of eel-grass, of which we had secured a good supply beforehand. By sunrise the gale had increased to one of great fury, and lines of breakers one after the other extended along the shores in front of the whole beach. The waves rapidly wore away the outer beach, and the men worked as if their lives depended upon it, to keep the ocean out of the cut. In this they succeeded till about 8 a. m., at which time the level outside was 4 feet above the level in the bay. By this time all the sand convenient to use at the barrier had been thrown upon it, and carried away by the waves. Human power could no longer maintain the barrier, and I directed the men to abandon further effort. They barely escaped to the side of the cut when the waves leaped the barrier and swept it away with them. Such a rush of water as now came pouring into this opening looked as if it must inevitably cut away the beach and make the inlet too large to close again. The water was driven before the tempest into a cut 60 feet wide and mostly 8 to 10 feet deep, with a head of 4 feet. This force rapidly widened the passage to about 140 feet, mostly by undermining the east side. The current, however, could not carry the sand out of the cut, but dropped it at the bottom. The wind, as it changed more to the westward, brought more and more sand along the beach and into the opening on the west side. The waves also undermined the east side by their direct impact. The filling up became very rapid as the tide began to fall, and by sunset the outside beach, that is, the part specially formed by the waves, was again continuous across the opening. It was observed during the height of the inflow that the current did not follow our artificial channel through the flats, but turned to the eastward along the natural water way and onward in the natural channel through the shoals. This course was clearly marked by the bubbles which formed on the water-surface at the edges of the cut as the undermined sand fell in. This showed conclusively that this artificial channel through the shoal might have been dispensed with. In consequence of the current not following it, it was not filled up with sand, and still remains.

I was very dissatisfied with the result, but I had followed the best light I could get, and had learned some things that could be learned in no other way. In that, as an engineer, there was some compensation. But I was really unhappy when I thought what a loss and disappointment it was to the people of Edgartown, not only because of its failure, but on account of its natural discouragement to future efforts. I had been personally on the ground almost a month. Other duties compelled me to leave, and they have also delayed this report. Mr. Van Ingen remained behind to try again on the next time of high-tides.

At about noon on October 31, Mr. Van Ingen began at the cut, with *forty men and six teams, to* dig a narrow trench, 10 feet wide and 3 feet

deep at high-water, sufficient to set the water flowing, but a storm filled it up.

Again, on the 6th of November, he made at the cut a channel 6 feet wide and 3½ feet deep at high-water. This he kept open during two outflowing tides, the second one giving him a head of 2.7 feet. The gravel at the ocean end defeated all attempts to deepen it there, although he had men shoveling all they could. A southeast storm closed it all up again.

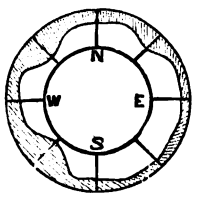
These operations by Mr. Van Ingen to effect an opening with the outward current show that there is little chance of success in the method of merely making an opening sufficient to cause the water to flow, even when aiding the operations of nature afterward by all the stirring and digging practicable, unless, as he says, "there should be several days of smooth sea in addition to a fair head of water." Even then it is so uncertain that I think there is no practical reliance to be placed upon such plan.

I will conclude this narration of our operations with some general meteorological considerations which bear upon the subject, and which have been deferred till this place in the report because they have not been made controlling features of the work on account of their uncertainty, although of vital importance to success. It is well known that our periodical meteorological phenomena are subject to very wide limits of variation. The changes between summer and winter, although on the average gradual, are frequently affected by days in close proximity in which the ranges of temperature vary greatly in both directions on the thermometric scale from the mean-months—are exceptionally cold or exceptionally warm; and the same is true for whole seasons.

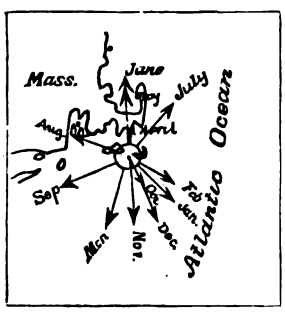
Professor Mitchell, in predicting the time of tide for opening the beach, also states, as already quoted—

> There will also be a decided advantage in selecting a period of strong winds from north to east, but winds from the opposite quadrant will prove very unfavorable.

The best authority I can find for determining the season of the year when winds from the favorable quadrant are likely to prevail is Professor Coffin's "Winds of the Northern Hemisphere," in the sixth volume of the "Smithsonian Contributions to Knowledge." From this is taken the annexed diagram, on which the shading at the different points of the compass are proportional to the time during which the winds prevailed from those points during a period of four years' observations at Nantucket.



From this same work (Plate XI) is taken the following diagram, which shows the deflections of the wind from its mean annual course in the different months of the year, the relative amounts of the force being shown by the length of the arrow, exclusive of the head.



The first of these diagrams shows that the mean of all the forces of the wind, or their resultant, is a west wind, and the second diagram shows that all the winds from the favorable quadrant referred to by Professor Mitchell are between September and November, inclusive, in the autumn, and in March in the spring. From these we conclude, as far as we can conclude anything

from them, that our work was carried on so as to make the opening at the times when winds from the favorable quarter were most to be expected.

As before stated, our isolated position cut us off from receiving the often useful warnings of the Signal-Bureau of the War Department.

I have since obtained through the courtesy of General Myers, United States Army, Chief Signal-Officer, copies of the weather-maps from midnight Saturday until midnight of Monday, extracts from which I give below. It will be seen from them that if I had been in telegraphic communication, the predictions would not have altered my arrangements. At 7.35 a. m. of Saturday, the 25th of October, there was no storm-center reported. At 4.35 p. m. it was predicted that the area of low barometer in Kansas would develop into a storm-center, moving northeastward on Sunday, but—

For the Middle Atlantic States and New England, winds back to northeast, with continued high barometer and clear, warm weather.

This is apparently a favorable indication for Sunday night in regard to high tides. The prediction itself was true as to the weather. On Sunday, October 26, 1 a. m.—

A storm will continue to develop in the Lower Missouri Valley, moving northward over the upper lakes, preceded by northwesterly winds, and snow during Sunday.

At 7.35 a. m. Sunday the storm-center had moved northward into Wisconsin—

And will probably move northeastward over Upper Michigan. For New England and Middle Atlantic States, southeasterly winds.

Sunday, 4.35 p. m.—

The storm on Lake Huron will probably move northeastward. For New England, easterly winds.

Monday, October 27, 1 a. m.—

An area of low barometer that was Saturday night in Missouri and Kansas has moved northeastward over Lake Huron, and has very rapidly developed into an extended disturbance. * * For the Middle and Eastern States, brisk and possibly high southeast and southwest winds.

This information on Monday morning would not have been in advance of our actual experience. In fact there was none of it that, if received at the time made, would have warned us against probable adverse conditions until it was too late. At 7.35 a. m. the storm-center was still near Lake Erie, but by 4.35 p. m. it was central just north of Portland, Me. From the positions of the center of the storm, as located on the last two charts referred to, it must have moved nearly at the rate of forty-five miles per hour in the intervening time.

The weather-charts show a velocity of the wind at 7.35 a. m., October 27, of twenty-eight miles an hour, but I should think it exceeded this at Edgartown, and continued as violent throughout the day.

General Myers has also sent me the chart showing the course of the different storm-centers during the whole of October. The most favorable one for high-tides was on the 6th, 7th, and 8th of the month, but its course was out at sea, and could not be predicted. No other favorable one occurred during the month. On account of the injurious effect of the waves in storms, I believe it is better to have a period of calm than even a northeast wind. But even calm weather, as far as we are able to determine it on land, will not insure us quiet seas, for it frequently occurs that the most violent waves roll in upon our shores the effect of storms far out at sea, of which we have no warning.

Without going further in this report, the reader can form his own opinion as to whether the failure to accomplish the result desired was due to unfavorable conditions which we might reasonably expect to escape from in another trial. For my own part, I regard success in the way proposed so uncertain that no effort should be spared to increase it by study of the conditions involved and in search for a more promising project. This naturally leads us to the following chapters.

CHAPTER III.

PRESENTATION OF THE PHYSICAL FEATURES AND FORCES CONCERNED IN THE FORMATION OF COTAMY BEACH, AND IN MAKING AND CLOSING OPENINGS THROUGH IT, WITH A NEW PROJECT FOR MAKING AN OPENING.

I have arrived at a point in this report where we must consider what to do in the future prosecution of the work.. My views are now materially different from those on which the former project was based, and are derived from knowledge gained by recent experience, added to that before obtained from others. For the purpose, therefore, of having in one place all the facts in regard to the formation of the beach which I possess, I will give a connected description of the physical features as they appear to me.

THE BEACH.

The situation of Martha's Vineyard Island exposes its southern side to the full force of the ocean waves. The prevailing direction of these is such that the materials which compose the margin of the beach are swept along the shore from west to east, although there are times (of variable period) when the movement is in the opposite direction.

Reliable observation has determined that the beach-material is derived from the cliffs at the west end of this island, which are being undermined by the waves in storms. The way in which the waves cut to waste away a shore and move the material along it in their prevailing direction has been frequently described, and may be assumed here as a part of common knowledge. On reaching head-lands, this material is dropped on the sheltered side, and if the current past these points is strong enough, the material is washed away. Frequently only "spits" are formed, tailings of the deposit of the shore-drift, merely indicating the prevailing direction of the movement. When the wave-force is powerful, these deposits may extend entirely across the indentations of the shore, inclosing the space between the head-lands and causing fresh-water ponds to form inside of them. Some of these ponds periodically rise so high as to burst the barrier, and sometimes this operation is aided artificially, thus draining the interior and restoring a connection with the ocean for a while. The artificial openings that have been successful have, so far as I know, been confined to these fresh-water ponds. Sometimes, when the inclosed area is large and the rise of the tide considerable, an inlet is maintained by the ebb and flood, as at Port Jefferson Harbor and Fire Island Inlet, on Long Island, New York. In rare cases, like Cotamy Bay, we have seen the inlet direct from the ocean maintained for an unknown period of the past by the tidal circulation, finally closed up, and being at the same time connected by another inlet with Nantucket Sound, it cannot become a fresh-water lake and rise to a level sufficient to burst the barrier.

Thus it is now at the south side of Martha's Vineyard. The drift of

the material from the waste of the cliffs on the west end of the island has, in its eastward motion, closed the space between all the head-lands with a continuous beach till reaching the Muskeget Channel. It there meets with a powerful current, by which the sand is swept partly into Nantucket Sound and partly out to the ocean, forming extensive shoals in these waters.

The people in this vicinity call that part of the beach which is built by the sand blown by the wind and arrested by the plants "*the true beach*," and the part lying just seaward, built up by the waves alone, and washed by them, "*the false beach.*" They use the words "true" and "false" in the sense of "permanent" and "changeable," because the first undergoes but slow alterations, while the other changes with every change of wind, generally, throughout most of its extent, increasing with easterly winds and decreasing with westerly winds. More correctly speaking, the changing beach is the real beach, and the other a dune formed from it. It is necessary, in considering the nature of this "littoral cordon," to distinguish between these two parts of it; but as it is generally the custom, in speaking of Cotamy Beach, to regard the word "beach" as meaning the whole of it, I shall preserve that signification for the word and designate the other parts by prefixing qualifying words relating to their different formation.

There is a limit to the height of the beach formed by the waves, but where this is aided by the winds and plants take root, there is hardly any limit to the height that may be attained by the accumulated sand arrested by the plants. The comparatively little height attained by the dune portion of the Cotamy Beach attests what the surveys show—that it has, in recent times, been much undermined by the waves on the ocean side. Wherever a beach like this attains permanency, not only does its height become great, but marshes form along the margin in the inclosed bay. The remains of such marsh, now buried under the dune, or showing an edge exposed to the ocean waves, indicate a former period of quietude along this beach which it has not had for many years.

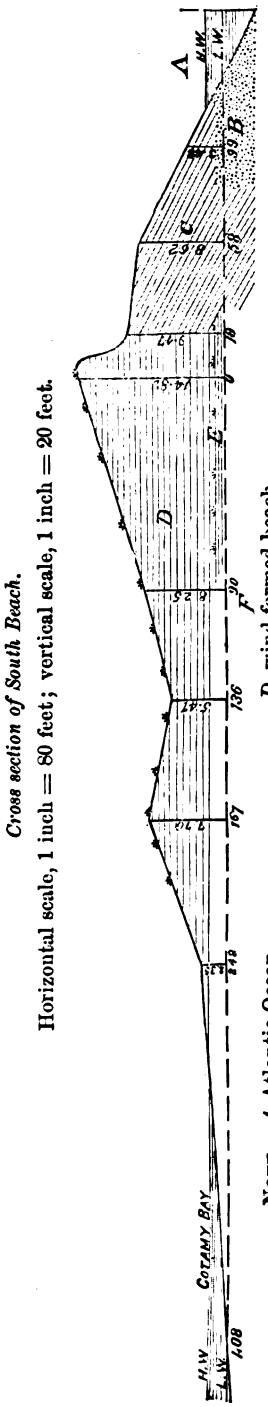
Annexed is a profile (horizontal scale one-fourth of vertical scale) through the beach, taken at the place where our excavation was made. This is at one of the narrowest places, but the height is as great as it is anywhere. Beginning on the ocean side, there is—

1. The belt of pebbles and gravel just below low-water level. Its exact extent we do not know, but it is probably as much as 6 feet deep.

2. We have the wave-formed beach, shown by the inclined shading lines, and these lines indicate a kind of stratification which it has in this direction. Its width is very variable; its height gives about 7 feet above ordinary high-water, being the limit to which the storm-waves cast up the sand; the breakers outside prevent the waves reaching very great heights.

3. We have the wind-formed beach rising 5 to 6 feet above the level of the wave-formed beach. It is nearly horizontally stratified. Under its highest part we found, buried up, a former salt-marsh, which must have grown, in a period of repose, at the inner margin of the beach. Men now living remember when it formed the inner margin of the beach. Underneath this marsh-sod, from 3 to 5 feet below low-water, there is a layer of clam-shells, mostly such as are now living inside the bay, near the same level, but which, inside, now live also even above low-water level. These shells under the marsh-sod, mostly the *Myacidae*, fully grown, are in the position in which they lived, and must then, of course, have had free communication with the water of the bay. The marsh-sod seems now at the level at which it grew.

This section may be taken as representing the general form of the beach. In some places it is much wider, reaching a width as great as 830 feet. At both the east and west ends of the bay the wind-formed beach is of a less height, not more than a foot or two above the part washed by the storm-waves, and here the beach-grass has not become well established. I do not think that the permanence of the beach depends to any great extent upon the part taken by the winds and plants.



Cross section of South Beach.

Horizontal scale, 1 inch = 80 feet; vertical scale, 1 inch = 20 feet.

NOTE.—*A*, Atlantic Ocean.
B, belt of gravel and pebbles.
C, wave-formed beach.
D, wind-formed beach.
E, remains of marsh-sod, in position as it grew.
F, level of beds containing shells.

The expressions "increasing waste" and "beaten back," applied to this beach, do not convey my idea of the operations going on, and furnish us no ground upon which to reason as to the effect of changing conditions. The idea of being swept along the shore is consistent with wasting, but not with "beaten back;" but unceasing waste is inconsistent with the existence of the beach itself.

The waste along the south shore of Martha's Vineyard, in one sense, is confined to the high cliffs near the western part, at the Nashaquitsa cliffs and Gay Head, and is there intermittent, mainly taking place in storms. As this wasted material is moved eastward by the waves, it forms the beaches across the bays, converting all but Cotamy Bay (with its northern outlet) into ponds.

It seems evident that if this waste material at these bluffs was furnished as fast as the waves could move it eastward, each part of the beach would be supplied with material nearly if not quite as fast as it was worn away, and a considerable degree of permanency would be given to the beach. If, on the other hand, there should be a lack of material furnished, the wear upon the beach already formed would begin, and, its waste not being replaced, a recession of the beach would follow. The water-formed beach would at times all disappear, and the waves would then undermine the wind-formed beach behind it. This high beach has its crest next to the waves, and at its present height, about 12 feet above high-water, a recession of 100 feet would in many places bring it down below the level of the extreme tides. At such a time, with favoring tides, a natural opening might be formed. At first glance one would be inclined to say that the wearing away of the beach at Cotamy was a consequence of the gradual wearing away of the whole south shore of Martha's Vineyard; but, if my reasoning be correct, a diminution of the wearing away at the cliffs which supply the material, or

a less amount of sand furnished by them, would be the cause of the increasing waste at Cotamy Beach. Nothing seems more probable than that the rate of wear of the western cliffs must have been irregular, both in extent and in the quality of the material, so that in this alone we have probable source of change enough to cause Cotamy Beach at one time to disappear and leave Cotamy Bay open to the sea, and at another time closed by a beach, as now, with the intermediate condition of an inlet. The evidence of the first condition Professor Mitchell gives, by referring the effect of the action of the ocean waves at points in the bay where they could not now reach, and could not have reached at any time since it was known to Europeans.

It is not improbable that there is less erosion now than formerly at the Nashaquitsa cliffs, as they have receded behind the partial protection of Squipnocket Point.

A diminution of the waste at these cliffs, according to my idea, involves an increasing waste at the beach in front of Cotamy Bay; *vice versa*, a large supply of waste material from the cliffs implies a period of rest or even of accretion at this beach. We have, largely, conclusive evidence of such former period of repose in the remains of the salt-marsh which we dug into near the outer edge of the beach. This marsh is now entirely covered with dune-sand, but it must have been formed on the inside margin of the beach, beyond the reach of this drifting sand, and a considerable period must have been required for it to grow; entirely inconsistent with such rapid changes as we have seen in the last twenty-five years. This marsh was about the mean level of the bay, and about 1 foot thick. Underneath it was the usual layer of shells of the species now found in the bay. The beach must have remained nearly stationary while this salt-marsh sod was forming on the bay side. At present there is no such marsh to be seen in Cotamy Bay.

Mr. Wm. H. King, a resident of Edgartown, employed by me, says of this former marsh: "It was formerly about a mile long and 30 rods wide in some parts, and in others not more than 10 rods. On the lowest parts the tide ebbed and flowed. On it sedge, salt, and black grass grew. It began to be covered with sand about fifty-five years ago, and it finally disappeared beneath the beach about twenty-five years ago. It has been known at least as far back as seventy-five years.

This effect upon the beach at Cotamy, arising from changing conditions of the receding cliffs to the westward, must have been gradual, and operate over considerable periods of time, such as I have associated with the growth of marshes inside the bay.

The changes at Cotamy Beach, therefore, I attribute alone to the transporting power of the waves along the shore. If more material is brought, under varying circumstances, than can be carried away, the beach grows and remains permanent. If the supply is less than the waste, there is a recession. In either case, a rapid transportation of beach-material across an inlet might close it, and even opposing winds might unite to produce this effect. It is important to recognize this, in order to realize the great power that is at work to close an outlet after it has been artificially formed. All the material of the beach in its changing conditions must pass the opening, and judged by ordinary measurement it is truly enormous. The waves do not beat back, they run along the margin and carry away.

While I regard the variations in the amount of recession of the Nashaquitsa cliffs and in the quality of the material they afford for making beaches as most important, there are, besides, meteorological conditions

which may operate more or less effectually for one season, or even for several seasons, such as the greater or less prevalence of strong southerly winds over northerly winds. These variations I believe to be of very great importance in the formation of the beach. It is generally thought that *strong* southerly winds cause the waves to wear away the beach, but that *mild* southerly winds and northerly winds in general, when not producing heavy waves on the shore, cause an increase of the "*false beach.*" We can see from this that a long continuance of heavy southerly winds might not only remove the "*false beach,*" but undermine the wind-formed portions, until what remained would be lower than the part formed by the waves. If this wind was westerly, no opening would form under such conditions, for the waves would constantly bring a supply of sand from the west and keep the wave-formed beach up to its full elevation. The contrary result might happen with an easterly wind, for then the eastern portion of the beach could derive no supply of material from the Muskeget Channel to take the place of that moved away. Whenever the undermining with a southeasterly gale had gone far enough to bring the beach below the level of the tides, there would be a minimum supply of material to restore the waste. At such times, too, the most rapid and highest rise of the tides would occur, and the ocean have the best opportunity to force its way inward. This view accords with the fact that all former openings have been near the middle of the Cotamy Beach, or east of the middle part.

Until some such wearing away occurs, it is not conceivable how any storm could break the barrier. Such a condition of things, however, must be of rare occurrence. The storm of November 13, 1871, (to ascertain the effect of which was one of the objects of the survey made under General Thom) was a very remarkable one. The wind was from the east, and the tide rose suddenly and very high, but it left no effect here. No recorded ocean or bay tide could overcome the beach as it now is.

There are minor peculiarities found on the beach itself, as it is worn away, which give a different rate of recession to different parts. Where it is composed of material thrown up by the waves it is nearly all sand, and generally homogeneous; but, as we have seen, the recession has gone so far that marsh-sod formed in the bay is now found in places projecting against the ocean-waves. This would give a different local rate of subsequent change. The waves, too, probably act somewhat unequally, owing to differences in depth in front of the beach. These irregularities exist on the outlines of the beach, producing points and hollows, and these, too, somewhat further modify the wave action.

This endeavor to understand the forces operating to form and remove the beach seem to me called for, and the inferences drawn seem to be entirely in accordance with known facts.

Imperfect as the state of our knowledge thus derived may be, it is all we have. No human eye witnessed the former openings and closings of the beach, nor noted and recorded the changes that preceded, accompanied, and followed them. That there was evidence of great wasting away of the beach at its eastern part in 1856, when Professor Whiting made his survey, after the new opening formed, seems to be affirmed by him in his report, page 117, annual report United States Coast Survey for 1856. He says:

> This action of the sea indicates a gradual wearing away of the southern shore of the island, and I think in this particular locality the beach may eventually be entirely swept away or washed-in upon either shore, leaving the bay between the Vineyard and Chappaquiddick an open chop. * * * *
> A heavy gale, with heavy and continued breakers, may throw up another beach and close this new opening, but I think the indications point to its being finally swept *away.*

This is a condition of things which may naturally occur again, and form a new opening. But not only must there be a great wearing away of the beach, but a very favorable combination of the tides. A south-east gale at the period of greatest high-tides, might raise the level outside of the beach, so as to overtop it in a worn condition, at a time when Cotamy Bay was 5 or 6 feet lower. Then a rush of a broad sheet of water across the low narrow beach would sweep much of it into the bay, and the succeeding high-tide in the bay might complete the work by its outward flow. Mr. Fisher, a well-known resident of the locality, informed me that these were the circumstances attending the formation of the last opening. He says the break in the beach was made by the incoming tide from the ocean, and not from the bay outward, as is generally supposed. Professor Whiting also confirms this idea of the formation of the opening, for he says, "the beach on either side of it has been beaten in a thousand feet." I would suggest *swept-in* rather than *beaten-in*. This action requires a deep space in the bay behind the beach to receive the sand. This erroneous idea of the opening being from the bay outward has grown up from the fact that the breaches through beaches made at the ponds have all been outward. But, as said before, there is no analogy between the two cases, the ponds having a head of 8 to 10 feet sometimes, and this entirely independent of the tides, so that the current was not intermittent.

If my conclusions are correct, it would seem that to pursue the course of nature in making an opening we should not attempt a narrow cut through the beach at some arbitrary point. We should take that part of the beach where natural openings have formerly existed, and there remove the sand over as broad a space as possible, leaving a natural bulk-head between our excavation and the waves, and let the latter destroy this bulk-head at the time this natural action would effect it, for at such times the conditions of wash would be most favorable to the opening.

We are, however, prevented from doing this by the great width of opening that we should have to initiate; the new opening, at the time Professor Whiting saw it, being 1,400 feet wide. I have, in a previous part of this report, discussed the width of a natural opening, when directly opposed to the ocean, which seems from past observation to have required 2,000 feet. A narrower width, 500 feet, was sufficient for the period when the opening was presented to the Muskeget Channel, and the beach formed the side next the ocean. This was the most favorable position for the opening, as far as the ordinary waves were concerned, and the strong current of the channel prevented any bar forming at its mouth. It was probably filled by the protecting beach itself being washed into it by the storm-waves at a period of no current, which recurs at every change of level between the two sides of the beach. Had this outer beach been properly revetted so as to prevent the sea washing it away and into the narrow channel, I think the opening thus presented to the Muskeget Channel would have remained open.

DEFINITE PLAN PROPOSED.

All things considered, I believe the only practicable place for an artificial opening is at the east end of the bay, between the beach and the fast-land of Chappaquiddick, so as to connect direct with the Muskeget Channel, and that we should endeavor to restore the conditions which existed when the opening was at this point and had a width of 500 feet. To prevent this being filled up we must protect the outer beach

by rip-rap, and by all the appliances, such as fences, brush, &c., that will aid in arresting the sand blown by the wind, and build the beach up above the power of storm-waves.

The swift current of Muskeget Channel will prevent the sand lodging so as to fill this opening up. If we can secure permanence to the beach forming its outer chop, the waves here will have less power than when exposed direct to the ocean; they will not, therefore, act so powerfully to throw sand into the opening, and they will not so often form impassable breakers at the entrance, rendering it useless to boatmen in heavy storms, as any direct outlet to the ocean would.

The opening, too, at this point, leads directly to the place that pilots and fishermen desire to go. It is designed to be permanent, and the cost of executing is not to be repented.

The plan under which I have operated has the following objections:

In the view of the fact that the opening, when formed, would move eastward and close again, it was located at the western side of the bay, where the difficulties of making the opening were the greatest. It was believed to be easy and cheap, but it is not, and a repetition of the operation, if once successful, should be avoided. An unsolved feature of that plan is, how to construct a bulk-head across the opening that will withstand unfavorable storms, and be readily thrown down artificially when thought desirable. This opening could not have been used by the boats in storms on account of breakers.

The tidal circulation, in its influence upon Edgartown Harbor, is believed to be the same in both cases; but I have reserved a discussion of this effect until I come to consider the importance of the work itself.

The work to be done to carry out the plan I propose would be to construct a breakwater of heaviest granite blocks on the south side of the proposed opening, and at right angles to the current of Muskeget Channel; the outer end of this breakwater to be on line with the trend of the east shore of Chappaquiddick Island, in about 6 feet of water; the shore-end to be firmly anchored in the beach, and the beach protected by short granite jetties about 50 feet in length and about 50 feet apart, and united at the shore-ends by a continuous line of riprap. Lines of fence are to be built, or rows of dead cedar trees set out to act as sand-catchers on the beach, and thus cause it to augment more rapidly.

I believe the whole width of channel needed will have to be dredged out, and possibly may amount to 500 feet. I have, however, limited the estimate to a width of 300 feet. and depth of 4 feet at mean low-water, which will be about one half the other in amount of material to be removed.

The breakwater will be about 300 feet long, 20 feet wide on top-side slopes of one upon two, and 14 feet high. The riprap protection to the outer edge of the beach will extend 3,000 feet, and will consist of short jetties about 50 feet long and 50 feet apart, to be connected by riprap at their shore-ends. These small jetties are to be triangular in cross-section, with side-slopes of 45° and 8 feet high. The storm-waves break so far outside of the beach that this will be sufficient protection to it.

ESTIMATES.

Granite for breakwater, jetties, and rip-raps, in blocks not less than a ton weight, 30,000 tons, at $4.50	$135,000
Fences or trees to arrest sand	5,000
Dredging, 330,000 cubic yards, at 30 cents	69,000
Superintendence	20,000
	220,000

CHAPTER IV.

IMPORTANCE OF THE IMPROVEMENT.

The inlet to Cotamy Bay was valuable to the fishing interests as pursued in small boats, such as are generally used by fishermen along our shores, and was also of service occasionally to some vessels so unfortunate as to be in distress on this coast, by enabling these men to reach her and act as pilots. If these objects alone were to be considered I do not think they would justify the expense of an opening. The main object claimed for the operation, however, is the influence in preserving the depth of the entrance to Edgartown Harbor.

So far as the survey made by Professor Whiting in 1871 goes, it does not appear at all conclusive that any injury to this harbor resulted from the closing up in 1869. The injury feared is based more upon inference than observed measurement. There was no survey to compare it with but the previous one of 1846, and many of the changes shown may have been as much the effect during the succeeding twenty-three years, while the Cotamy Beach remained open, as during the last two years during which it was closed. The following changes were noted:

1st. One foot more of water can now be brought into the town-basin over the bar. 2d. The apron of sand within Chappaquiddick Point has extended so as to reduce the depth all the way across the channel and impair the holding-ground. The cross-section most encroached upon has lost about 25 per centum of its area. 3d. An increase of the bulk-head or shoal in the broadest portion of Cotamy Bay has occurred, and amounts to nearly 1,000,000 cubic yards.

The increase of depth, Professor Mitchell says, had been so gradual as not to be noticed by the people of Edgartown, but the extension of the "apron of Chappaquiddick Point had excited attention by its recent advances." The addition to the shoal in Cotamy Bay could not directly effect Edgartown as a harbor. It was of course due to the opening and not its closing up.

The anchorage which has suffered since the survey of 1846 was inside and past the town, and cannot be considered important in the point of view of a harbor of refuge. In fact, in all winds except from the north and northwest the anchorage outside the light-house is good, and these, which the outer harbor furnishes no protection for, are generally accompanied by clear weather, and are favorable to vessels keeping on their course.

Professor Mitchell thinks that superior depth at the entrance of Edgartown over that at Nantucket "*is due to the existence of a southern opening in the former case.*" If these entrances were in every other respect precisely alike I would agree with him in this opinion, but the other conditions are so different that I do not think the reason sufficient.

We have already spoken of the strong currents of water which flow between the Muskeget Channel and the eastern entrance. The numerous shoals attest the great amount of sand they sweep along in their course. In this broad part of the sound the prevailing northwest winds must cause the waves to throw much greater quantities of sand upon the north shore of Nantucket Island than can ever reach the north shore of Martha's Vineyard, and this sand swept along the shore of Nantucket by the waves is sufficient, in my mind, to account for the very different conditions of the two inner harbor entrances. On the whole, I agree with the final conclusion of Professor Mitchell, that "until we have still another survey we must infer that the two years' closure of the beach has not affected the bar" at the entrance. With the remainder

of the appropriation unexpended, $1,385.48, I would recommend this survey to be made the coming season. From this we can ascertain what the injury has been in the last five years, and whether it is not better to dredge at Edgartown than at Cotamy Beach.

CONCLUSION.

I cannot find ground at present sufficient to justify an appropriation for making the only opening in the beach which I consider practicable. But unwilling to stand in the way of an object which others have thought so desirable and easy of accomplishment, I respectfully recommend an appropriation of $22,000, the original estimate, to be paid to any one who will make the improvement desired; letting it by contract to the lowest bidder, under sufficient guarantee that he will make a proper effort, and receive compensation upon succeeding.

APPENDIX.

Report of Mr. A. S. Van Ingen, Assistant Engineer.

ENGINEER OFFICE, U. S. A.,
Newport, R. I., December 26, 1873.

GENERAL: I have the honor to make the following final report of operations for the opening of the South Beach, with a view to the restoration of the direct tidal flow between Edgartown Harbor, Massachusetts, and the ocean.

In accordance with your instructions of August 11, 1873, I proceeded to Edgartown, Mass., August 15, to assume charge of the work already in progress. The plan of operations proposed was to dredge a 6-foot deep channel through the flats in Cotamy Bay, from deep water to the beach, so as not only to assist in drawing the waters from the bay toward the opening when made, but also to serve as a navigable channel for the tug used in attendance on the dredges and scows, and for vessels bringing material for jetties, which it was thought would be needed on the ocean side of the beach to insure complete success.

The west line of the proposed cut through the flats and beach had been marked out in accordance with the plans of Lieutenant Colonel Thom, United States Engineers, with the modification of saving 60 feet in distance by running from deep water more directly for the beach, and striking it 660 feet east of the point selected by him. A dredge, hired of Mr. Morris F. Brainard, of Albany, N. Y., began work July 21st on the first and west cut. The water was so shoal that it was impossible to use scows to advantage, and the material was thrown over the side. On August 10 a second dipper-dredge, belonging to Messrs. Staples & Phillips, of Taunton, Mass., was placed on the work, dredging up from the beach on the first cut. It was intended to have the tug from Albany, N. Y., previously chartered, arrive at the same time, to tow away scows, so as to begin the second cut at once, before the sand should have washed back from the bank; bad weather for two weeks delayed it.

On taking charge then, August 15, I found these two dredges at work digging from opposite ends of the first cut and throwing all material over the side, they being only 550 feet apart, and no tug on hand. A portion of the bank thrown up had been washed back into the cut at the inside channel, near the beach, by the severe gale of August 14. On the 21st the two machines had so nearly met that one was withdrawn from the first cut and set to cleaning out the sand washed back; the other completed this cut, made a side opening for the flow of the deep water west of the bank, and then began the second cut at the north side of the inside channel, (shown on the map,) the material being discharged into scows. As the tug had not yet appeared, these scows, lightly loaded, except at very high tides, were warped out 600 to 1,000 feet to the eastward and dumped in the deep hole shown on the map.

The tug reported August 26; one dredge was immediately started in at the north end of the second cut, the tug towing her scows away to the eastward about 4,500 feet; the other machine continued the same cut from the inside channel, the scows being warped away as before. After carrying down the second cut a few hundred feet, so much trouble was encountered in turning the tug in the two cuts on account of the running back of the sand, and the forming of shoals, that a third cut was begun September 3. The work of dredging from this time progressed but slowly on account of the

rapid movement of the sand, shoals forming alongside the dredge every night; and this, notwithstanding the scows from each dredge were removed from the narrow cut at the close of each day, so as to give an uninterrupted flow to the current. It was impossible also to keep the sand from running through the scows. Much delay was occasioned by having to pick up these numerous shoals.

On the 8th of September the sloop Mary Adelaide, with tools and material, arrived from Newport, and discharged her cargo on the beach.

A rough building was erected on the beach, to serve as a tool-house and afford shelter for the men in rain or at night. A board bulwark, 6 feet high, was built across the south end of the slough through the beach, as protection against an unusually severe storm during the progress of the work. This was strengthened by throwing up sand on both sides 2½ feet high.

On September 15 six teams began the scraping away of the sand from the beach down to about mean sea-level; it was all hauled away to the eastward, a distance of about 100 feet, with iron scrapers holding about one-ninth of a cubic yard, drawn by two horses. The prices paid per day were $2.25 each for horse and driver, and $2 for ordinary laborers.

During the latter part of September, a cheap dock, 60 feet long by 25 feet wide, was built at the beach on which to land stone, it being expected that there would be sufficient funds to build a jetty on the south side of the beach.

The two dredges continued as above until the second cut was finished, when the dredge, already on the third cut, was left to complete it, and the other one was set into the beach proper, where it had been scraped down to mean sea-level. Two cuts were carried in together, the material from the first being thrown over to the eastward and scraped away, and that from the second warped out in scows. The machine used for this work being in bad repair, as soon as the third cut was completed down to the inside channel Mr. Brainard's dredge took its place in the beach, and the dredge of Messrs. Staples & Phillips was discharged, as but one could be employed. The gang of scrapers and laborers was now increased so as both to level the beach ahead of the dredge and remove the bank thrown up from the first cut.

On October 7 you arrived in Edgartown, and from that time until October 28 took immediate charge. By that time it was found that the dredging in the bay had cost so much more than expected, that no jetty could be afforded; neither could a greater width than two cuts be allowed through the beach. The force of workmen was at once increased, the west bank shoveled back to an easier slope, the bulwark, not considered by you sufficiently strong, strengthened by throwing up an enbankment of sand on each side to the level of the top of the boards, the width at top being 1 foot; eel-grass was added on the south side and was found to make a very firm bank. Two gauges were set up, one at the dock in the bay, and the other on the ocean side of the beach; the latter was a piece of gas-pipe, graduated, sharpened into a wedge-shape and driven in the bottom. It stood several severe storms without changing its level more than one-hundredth of a foot, and was still standing when I left. These gauges were placed at the same level, and referred to the bench-mark established by the Coast Survey department in Edgartown, their zeros being 16.535 feet below the Coast Survey bench-mark on the water-table of the Martha's Vineyard National Bank, under the north front window. Low-water as established by the Coast Survey is 15.16 feet below this bench-mark. The outside gauge being exposed to breakers part of the time, did not indicate the minor fluctuations of the tide, but careful reading gave very good and accurate records of the rise and fall. The height of the tide was taken in the bay every 15 minutes, and in the ocean every half hour. By means of these the head of water inside and outside was determined each day; it was extremely irregular, sometimes unaccountably so. These records are presented in detail with this report, and from them are plotted the tidal curves, a copy of which also accompanies this and shows the differences of level between the two tides for each day.

Every effort was now put forth to make the final opening at the time of the next spring-tides, about October 23. A channel 55.60 feet wide and 6 feet deep was continued to the bulwark, on a line with the crest of the beach, and that was taken down. It was at this time that a tough turf, the remains of a former marsh, was met in dredging, which, it was feared, would present an obstacle to the cutting out of the current. The channel was therefore dredged 50 feet farther, and the dredge then ran ahead 20 feet, digging and throwing over the side so as to loosen up the bottom. This brought the channel to high-water mark on the ocean side. It was finally completed at midnight October 26, it having been your intention to open the channel that night as soon as a head occurred in the bay, which should have been about 1 a. m. The greatest head that morning was 1.1 feet, not enough to withstand the surf now beginning to roll in heavily. The wind was blowing strong from the south, increasing all night. At 1 a. m., when all hopes of a good head inside were given up, an embankment of sand was thrown up at the mouth, and strengthened from time to time with sea-weed and sand. By 9 a. m., October 27, the storm had increased so much, bringing in a heavy sea—the head of water outside being 2.2 feet—that the embankment was

carried away, and the water rushed in with great force, undermining the side-banks and carrying much sand with it. The head of water increased from 0, at 6.30 a. m., to 2.7 at 10.45 a. m. It was not till 2.15 p. m. that the water in the bay and ocean came to the same level. By this time the cut was filled with sand the width of the beach, and to such a height that no water would run out. The storm the next night was unusually severe.

After your departure, on the 28th of October, by your direction I remained in Edgartown to take advantage of any favorable state of weather and tide, and renew the attempt to effect an opening. The funds available were now nearly exhausted, so that only an inexpensive trial could be afforded, such as the inhabitants have themselves often made without success.

About noon of October 31, the wind blowing fresh northeast, and the water being smooth outside, a gang of forty men and six teams were set to work digging a narrow trench through the beach; a ditch 350 feet long, about 10 feet wide and 3 feet deep at high-water, was made by 5 p. m., when it was proposed to open it to the current from the inside. By that time, however, the wind had shifted to northwest, and a heavy sea had come in, so that it was deemed best to hold it until the next day, in hopes of the sea going down. This, however, did not take place, and the ditch was held with an embankment of sand until the morning of November 3, when it was carried away by another severe southerly storm and the ditch filled in as before.

Again, on the 6th of November, came a favorable opportunity. The sea was very smooth, the wind northerly, and the tides large. At noon a gang of men were set to work digging another ditch through the beach, making it 6 feet wide, and 3½ feet deep at high-water. This was completed at 11 p. m. The head of water in the bay was only $\frac{2}{10}$ foot, not enough to withstand the slight surf. The tide was now on its first stand, and it was not until 12 o'clock that it became higher, having in the mean time fallen $\frac{1}{10}$ foot. The outside tide had, however, fallen rapidly, so as to give a head of $\frac{4}{10}$ foot. The wind which had been northwest at 5 p. m. had again hauled northeast, and was blowing quite fresh. The bulkwark of sand at the mouth of the ditch was now removed, and the water allowed to run out, the whole force of men being kept at work loosening up the bottom with shovels and hoes. At first the current ran feebly, but became quite rapid for a short time about 2 a. m. The night-tides being less than the day-tides, the moon being at nearly its maximum north declination, the rise above mean low-water was only 1.5 feet, and the greatest head a little over 2 feet. At 3.45 a. m. the head had diminished to about 1 foot, and the current moved so feebly as just to withstand the ocean-surf, which had begun to increase. The ditch had widened to about 10 feet at low-water, but deepened very little on account of the hard gravel at the mouth, which could not be removed, though continually loosened. The mouth was now closed against the incoming tide with an embankment of sand, to be held until the next head inside occurred. During the morning the wind had hauled more to the south and east, and the swell and wind chop had increased outside considerably. It was evident that a southeast storm would be upon us before we could get the cut wide enough to hold its own, and that our labor would be in vain. However, at 12.30 p. m., with a head of 1.2 feet, the embankment of sand was removed, and the current again started out. At first it scarcely ran at all, being driven back at the mouth by the surf, but soon the head increased, and the current ran much more rapidly than at the previous head, sufficiently so to drive the sand 30 to 40 feet out, where it made a point toward the westward. The flow along shore was not swift enough to carry it out of our way, as we had expected. The greatest head attained was 2.7 feet, the tide inside having risen 1.15 feet higher than on the previous night. At 4 p. m. the ditch had widened to 27 feet at the mouth and 17 feet at mean section, but had been again prevented from deepening by the gravel at the mouth. The swell had so increased that all thoughts of being able to hold the ditch by an embankment were given up. The head at this time was 1.3 feet. The current continued to run out very feebly until 5 p. m., when the head was only $\frac{1}{10}$ foot. The water then flowed in, and by the next day the beach was filled in again as before, the high-tide outside washing over, but no water running out.

As I considered several days of smooth sea in addition to a fair head of water essential to the success of an opening, and these could not be expected at that time of year, and as even with favorable weather the gravel at the mouth might still prevent the cut deepening unless some effective measures were taken for its removal, and as there were no funds available for jetties or coffer-dams, I deemed it advisable to make no further trial.

The total length of cut made was 2,200 feet—60 feet wide in the bay and 55 to 60 feet through the beach, and 6 to 7 feet deep. The amount of material removed by dredging was 33,725 cubic yards, at a cost of 37.98 cents. The amount of sand removed by scrapers was 8,843 cubic yards, at a cost of 27 cents per cubic yard; of this, 4,177 cubic yards was composed of the surface-sand, from the 60-foot wide cut down to mean sea-level, and the balance was that thrown up by the dredge from the first cut and that removed from the sides to make an easy slope for the horses.

There accompanies this report a map on a scale of 200 feet to one inch, showing the locality of the work, channel dredged, &c., with sections of beach before the work commenced, and sections of the channel made; also, one sheet of the tide-records kept at the South Beach and two sheets of the tidal curves plotted therefrom.

In reference to future attempts to open a channel through Cotamy Beach, should any be authorized by Congress, I would recommend that a different site be selected for the opening, either at the point of the 1856 cut, suggested by me in my report of July 22, 1872, or at the extreme east end, as desired by the fishermen of Edgartown. But before any location should be chosen, I would suggest that a careful survey of the whole beach and vicinity, and especially of the east end, be made.

The greatest advantage claimed by those in favor of this latter site seems to me to be the rapidity of the along-shore current to remove the sand washed out of the opening, so as not to form a point, as was the case where the last attempt was made. The relative speed of this current at different points along the beach has not been referred to in any of the published reports on this subject. It is evidently more rapid at the east end, by Muskeget Channel.

Some measures also must be taken to remove the hard gravel on the south shore, the presence of which would, I think, prevent all deepening of the channel behind it. In good weather a dredge could work right through this without risk, being timed so as to reach the outside when the ocean had fallen to the level of the bay. Or sheet-piling might be driven out a short distance sufficient to protect the men inside from the waves, and this gravel could then be removed 2½ feet deep at low-water in this way; or substantial, stone jetties could be built out on both sides of the proposed cut on the south shore. Again, the sand removed from the beach should all be carried away, and not piled up on both sides of the cut to be washed in again when the channel widens.

Should the location of the old opening of 1856 be selected, the removal of sand would be easy. The beach is here, it is true, 750 feet wide, but not as high as at other points. There is good water inside all the way to the deep water at Cotamy Point, and a deep channel near the beach running to the eastward for a long distance. All the dredged material could be warped out into this inside channel; the only scraping needed would be in making a way for the dredge in the first cut, and she should afterwards re-dig all the material thrown out from the first cut. In this way the expense of a tug would be saved.

I make these only as general suggestions to be reconsidered after a thorough survey shall have been made, and to serve as points to be examined by those who shall have charge of such survey. The trial of last fall developed a lamentable lack of data for calculation, and while certain of these will be furnished by the experience lately gained, many more are needed.

It might be well to state here that while the plan proposed and desired by the inhabitants of Edgartown, viz, opening a small ditch and making the current do all the work, might succeed, it would be dependent entirely on "luck;" should there be smooth sea for a week at a time, with a good head inside, there would be some chance of success; otherwise not.

It seems to have been taken for granted in all previous discussions that the improvement of Edgartown Harbor could be effected only by the opening of a channel through the South Beach, to allow the flow of the tidal currents, and I have in the previous suggestions proceeded on this assumption. With reference, however, to the utility of such cut, simply as regards the preservation of the harbor of Edgartown, there seems to be some reason to doubt. This harbor is used as anchorage-ground only for a short distance past the light-house up to the point of Chappaquiddick Island, opposite the town-wharves. Vessels rarely go past this from the difficulty of getting under way readily. Even with the beach closed vessels frequently have trouble in entering the harbor as far as mentioned above, or leaving it against an opposing tide. Many vessels ostensibly seeking the refuge of Edgartown Harbor never pass beyond the light-house, finding sufficient shelter under the lea of Cape Poge, with the wind east of north. Professor Whiting, in his report on the effect of the opening of 1856, published in the Coast Survey volume for the same year, makes the following statement:

"This is now the main opening, and the tide is so strong through it as to materially affect the harbor and make it difficult for vessels in light winds to stem it in coming in from Cape Poge."

The opening of a channel through the beach will, then, in this respect, be a detriment to navigation, and consequently to the usefulness of this harbor.

There next arises the question whether the existence of an opening through the South Beach increases or decreases the injury to the harbor, and secondarily of Cotamy Bay, from the movement of sand. Professor Whiting, in the report cited above, continues:

"This action of the sea indicates a gradual wearing away of the southern shore of the island, and I think in this particular locality the beach may eventually be entirely swept away or washed in upon either shore, leaving the bay, between the Vineyard

and Chappaquiddick, an open chop. In this case the character and capacity of Edgartown Harbor will be greatly changed. Whether it will tend to deepen the eastern channel and improve it, or carry the sand, &c., through and deposit it in shoals toward Cape Poge, is a question for time to develop. The greater quantity and velocity of the current sweeping through the harbor will have a strong effect upon the shore and wharves of Edgartown. In fact, its influence is already felt."

Professor Mitchell, in his report, published in the Coast Survey volume of 1869, writes as follows:

"The soundings in the harbor of Edgartown, given upon the accompanying chart, executed by Mr. Marindin, differ from those which appear upon the chart of Lieut. Chas. H. Davis, (dated 1846,) in three localities of limited extent—

"1st. One foot more water can now be brought into the town basin over the bar.

"2d. The apron of sand within Chappaquiddick Point has extended so as to reduce the depth all the way across the channel and impair the holding-ground. The cross-section most encroached upon has lost about 25 per centum of its area.

"3d. An increase of the bulk-head or shoal in the broadest portion of Cotamy Bay has occurred, and amounts to nearly 1,000,000 of cubic yards."

These three changes are known to have occurred during the years 1846–1870, inclusive—twenty-five years. Of this time the harbor had the benefit of an opening through the beach for twenty-four years, being without it only during the last year. Unfortunately we have no data to show the condition of the harbor and bay just previous to the closing of the openings, so that it is difficult to determine whether these changes occurred during the twenty-four years or during the one year. Professor Mitchell considers the first, a change of 1-foot depth, to have been the work of years, because not noticed by the citizens of Edgartown. The second, a change of 25 per centum of area, he inferentially ascribes to the absence of an opening, because the shoal "had excited attention by its recent advances." If *recent* covers a period of only one year, then the change was remarkable certainly. If it extends further back, then it cannot be ascribed solely to either the existence or non-existence of the opening.

Professor Mitchell did not consider himself as having *certain* testimony with reference to the third change.

Is there, then, any sure ground for charging the disadvantageous changes to the absence of an opening? It seems to me not. The third change certainly is due to the sand washed in from the ocean through the different cuts, mainly at their breaking in. The widest part of the beach is found to be that east of the most western opening known, and as each cut moved eastward it continued the point first made behind it. It seems highly probable that this 1,000,000 of cubic yards was introduced in this way during the passage of the opening of 1856 to the east end. It is not probable that this amount of sand came from the north, nor that it was deposited in 1869–'70. Neither is there any probability of an opening increasing the depth of the bay, except in its immediate channel-way, and this is filled in again as the cut moves eastward. The tendency, therefore, while the supply of sand from the westward continues as at present, is that every successive opening will add to the width of the beach and the filling up of the bay.

Professor Mitchell, in the above-cited report, remarks: "Under the old *régimé* (existence of an opening) much more water flowed northward than ever returned.

* * * * * *

"When the tide was low in Cotamy Bay it was high in the ocean, so that the inlet and its outer-bar channels were broad and deep, admitting a great volume of water. On the other hand, six hours later, when the bay was full, the ocean outside was low, the inlet and outer-bar channel were narrow and more shallow, and a comparatively small volume of water could escape to the sea. These were the very conditions best calculated to keep the port free."

Is this latter statement correct?

As a general rule, other things being equal, the greater volume of water would carry the greater amount of sand. The inside head being smaller than the outside, and the current passing over the flats north of the beach, when the water was deeper than with the opposite current, the scouring effect on the flats, and consequently the amount of sand carried out, would not be as great as the current with the greater outside head and along-shore sand, and more effective scouring power on the flats would introduce into the bay and harbor.* If it is considered possible that during the absence of an opening Cotamy Bay may become filled up with sand washed in past Edgartown by the current, with small head, quite probable is it that the shoals opposite to and north

* Mr. David Stevenson, F. R. S. E., in his work on "Canal and River Engineering," pages 278, 279, says: "The harbor authorities placed gates across the entrance to the Slake, and, in order to render the scour more effective, impounded the water at high-tide, and at low-water allowed it to escape through large sluices formed in the gates, so as to act upon the harbor between half-ebb and low-water, at which period the scour is found to be more efficacious."

of Edgartown were formed with the sand driven through from the ocean and scoured out of the flats near the beach. And the second change cited by Professor Mitchell may be plausibly explained in this way: The north current ran so rapidly, that the sand from the ocean was deposited north of Chappaquiddick Point and the light-house. The south current, having less velocity, deposited the material brought back from these shoals south of Chappaquiddick Point, where the water spread out, after passing through the confined section opposite town. In this way was the "middle-ground" formed. It will be noticed, in passing, that the greater part of the 25 per centum change took place under the lee of Chappaquiddick Point from the south current, as would be expected if the above explanation is correct.

Let us next consider whether Cotamy Bay does not include enough back-water area to effectually scour out the harbor and prevent filling up. The bay down to the entrance at Chappaquiddick Point has an area of 70,447,125 square feet, covered each flood-tide 2 feet deep above low-water. Hence, the discharge opposite the town each ebb-tide is 140,894,250 cubic feet, and the mean velocity for the whole tide at the least section is 0.6 mile per hour. This is nearly sufficient to move along fine gravel, and more than is required to sweep along sand. But at certain periods of the tide the current flows much more swiftly. As the harbor is not exposed to heavy ocean waves, the tendency to shealing at its mouth would not be as great as at most of the harbors on Long Island Sound. Neither does there seem to be that similarity between this harbor and that of Nantucket, as stated by Professor Mitchell in his report already cited, as follows: "In my first attempt at anything like a scientific paper, over fifteen years ago, I called attention to the fact that '*about the same relation is preserved between the surfaces of the water at Brant Point and Weweeder as between Cape Poge and Wasque, and all the advantages which the harbor of Edgartown possesses over that of Nantucket would seem to be due to the existence of a southern opening in the former case.*' I remember that this was the result of a study made from actual levelings and careful observations, but had no connection whatever with any project of improvement at either of these ports." If this be true, then the harbor of Edgartown, its opening being gone, will rapidly fill up, as has Nantucket Harbor. On the contrary, the situations of the two places are dissimilar. Nantucket Harbor is exposed to the sand-laden currents flowing from south of Martha's Vineyard through Muskeget channel and out past Monomoy, and returning through this strait. Tuckernuck Bank and the extensive line of shoal-ground north of Nantucket are evidently the results of the deposits from these streams. The filling in of Nantucket Harbor is doubtless due to the same cause. Edgartown Harbor, on the contrary, is exposed to no such inflows of sand from the north. But a small portion of the Muskeget channel-current passes west of Cape Poge, while the current entering Nantucket Sound through the deep Vineyard Sound must carry very little sand with it. Edgartown Harbor seems to be especially guarded from deposits of sand by this peculiar location. The shoals north of the harbor are more probably due to the existence of an opening in former years.

There will doubtless be a gradual filling in of Cotamy Bay with wind-blown sand, no more and no less than would happen with an opening through the beach. This now takes place mainly opposite those parts of the beach not covered by grass. The encouragement of the growth of this at the now bare portions, by brush-protection, until it should be able to support itself, would be inexpensive and efficacious.

To understand how expensive improvements are warranted at this place it is necessary to know something of the interests at stake. Edgartown is at present a place doing no business at all with the mainland worth considering. It was at one time an important whaling port, but now this business has disappeared, probably forever. It consists of private residences, with only so much local business transacted as is required by the needs of the citizens and inhabitants of the east end of the island. In summer it is frequented by numerous visitors, accommodated at the various hotels of the town, and at "Katama," south of the town. Its nearness to the noted camp-grounds at Oak Bluffs makes it a busy place during summer, and it bids fair to equal this place in the future, having all the advantages, with none of the disadvantages, of the latter. The importance of the harbor as one of refuge has been referred to before. The steamboats running between this place and New Bedford find it necessary, in turning around, to go a considerable distance up Cotamy Bay, on account of the middle ground opposite the town wharves. The removal of this would not only be a convenience to these boats, but would also increase the anchorage-ground and give vessels a wider space to get under way, the contracted area inside Chappaquiddick Point being now the great objection to entering within it. There is no map in my possession with sufficient data on which to base an accurate calculation, but it would be safe to estimate the cost of the removal of this middle-ground and part of the point at from $75,000 to $100,000. This would give an anchorage-ground of 2,000 feet in length by 1,000 feet in width and 15 feet deep. I doubt if any opening through the beach will be guaranteed for a less sum by any engineer. A less amount might open the beach, and one-fifth of the amount might, and quite likely would, be expended without conferring any benefit on the harbor of Edgartown, whereas every dollar spent in dredging does some good.

But even should an opening be secured, the most enthusiastic supporter must acknowledge that it is liable to close eventually, and then the expenditure must be repeated.

There are, it is true, two interests that would not be benefited by the proposed improvement, and which are especially, even vitally, interested in the opening of a cut through the beach. Professor Whiting, in his report in Coast Survey, volume of 1869, speaks on this point as follows: "The question of how much this pilotage and fishing interest is worth, of what the value of the former may be to the general security of navigation, I will not presume to answer. It is not, however, an unreasonable supposition that within one year from opening an inlet and making such a channel-way, a vessel in distress outside may be saved by a pilot reaching her through this channel, and that the value of the vessel and her cargo may be worth as much or more than the amount it will cost to make the channel-way. This is apart from the question of the saving or loss of life." There are but few boats engaged in the fisheries of this place, and the receipts therefrom small, though sufficient to support perhaps twenty-five men. While our sympathies are certainly aroused for this brave and hardy class of men thus deprived of their accustomed means of livelihood, they should not so far prejudice our minds as to lead us to consider this class differently from any other set of men obliged to give up a non-paying business. This interest does not, thus considered, seem to warrant a large appropriation for the opening of a channel through the beach; and the same might be said of the pilotage interest. Coasters are too much afraid of the shoals south of Martha's Vineyard and Nantucket ever to run any risk of getting there, and all strangers are cautioned against them. A vessel drifting on to them unawares would sooner put to sea than wait in their vicinity for a pilot. It is doubtful if, in weather too rough for a vessel to put to sea, any of the pilots of this island could reach her. Still, this remains an undisputed fact, that if an appropriation by Congress were made, and the attempt to open the beach should succeed, and this opening should remain until some vessel so heavily laden as to be unable to put to sea should be caught, then, if it were not too rough, a pilot-boat from Edgartown might succeed in reaching her and saving a cargo worth more than the opening had cost, and the lives of men of incalculable value.

In conclusion, I see no need of treating this harbor any differently from numerous others in your department with one entrance, and consider the most certain and efficient improvement of the harbor would accrue from the removal of the "middle-ground" by dredging.

I left Edgartown and reported at this office November 18, leaving the tool-house and dock standing, and having stored the scrapers, tools, &c., with Charles Stewart, on the plains, and the office-furniture with Mr. C. B. Marchant, collector of customs.

I was assisted in this work by Mr. W. P. Jewett, assistant engineer, and Mr. S. E. Tinkham, assistant engineer, who faithfully performed the duties assigned them; as did also Messrs. W. H. King, George G. Cleveland, and Melatoah Mayhew, of Edgartown. I am indebted to many other citizens of Edgartown for their good intentions and assistance.

Very respectfully,

H. S. VAN INGEN,
Civil Engineer.

Maj. G. K. WARREN,
Corps of Engineers, Brt. Maj. Gen. U. S. A.

X 3.

WAREHAM HARBOR, MASSACHUSETTS.

At the close of my last annual report, August 30, 1873, the dredging operations under the appropriation of $10,000, approved June 10, 1872, had just been finished; those under the appropriation of $10,000, approved March 3, 1873, were begun September 1. Everything in regard to proposals, &c., for doing this work was given in my last annual report.

Before any improvement was made here, a depth of 7½ feet at mean low-water, (11½ feet at high-water,) was the greatest depth that could be found over the bars, and only in very high tides could the latter depth be found over the ridge just below the wharves. The channel was, besides, so very crooked, and the form of the harbor such that ves-

sels could only sail up or down with favorable winds, and the business of the town not warranting a tug, navigators were subjected to vexatious delays and losses.

From the first I deemed it better to improve the channel by cutting off the points and lessening the bends than to attempt to cut through the points, which had been suggested as an alternative proposition. I believed that more immediate good could be obtained by the course I adopted than by the other, and that the channel thus improved would be more permanent than the other, as being less artificial, and more nearly what the result of the combined natural causes had produced.

The survey which I ordered in the spring of 1873 confirmed my first determination by showing the greater feasibility of the course than I had at first thought. The depth of water to be given the improved channel was fixed at 9 feet at mean low-water.

The first appropriation of $10,000 was sufficient to complete a channel 200 feet wide, through a ridge connecting the east shore with the main portion of Quahaug Bar, of which it may be said to have formed a part, thus affording a tolerably straight passage around the main portion of the bar, which was not touched. Dredging was also begun on the upper bar.

With the second appropriation of $10,000 dredging was continued on the upper bar until the funds were exhausted, November 25, 1873. A channel about 120 feet wide was made around the upper bar, and the depth of 9 feet extended up to the town, leaving a channel nowhere of less width than 60 feet.

A large rock, weighing 28 tons, was also removed from the channel.

The amount of material removed during the working season of 1873, under both appropriations, which includes all that has so far been done besides the new survey and map, is as follows:

	Cubic yards.
From near Quahaug Bar	21,862
From near upper bar and up to the wharves	24,901
Total	46,763

Also, one rock from the channel, 28 tons. During the past winter, among other work, survey made by Mr. Van Ingen was plotted and the map finished. It is sent with this report attached to the report of Mr. Van Ingen, under whose superintendence the improvement has been conducted.

The further improvement of this harbor will require dredging at Quahaug Bar, to remove points where there is less depth than 9 feet at mean low-water, so as to make the channel there 200 feet wide and 9 feet deep; to remove a shoal opposite Barney's Point; to remove the main point of the upper bar and to widen above it, so as to make the 9-foot channel at least 100 feet wide in the straight portions and a somewhat greater width at the bends, to compensate for the greater room required by vessels in turning.

The outlines of the required channel are shown on the accompanying map.

In the report of the first survey, made in October, 1871, was one estimate for removing ledge and bowlder in Weweantic River of $3,000. It does not seem now that the removing of these properly belong to the improvement of Wareham Harbor, but there are rocks in the channel leading to Wareham Harbor just off the mouth of the Weweantic River, which have never been examined by us, and which should be removed, if practicable. We provisionally estimate the removal of these at $3,000.

The location of them is shown by four buoys, and the place is known to navigators as "Four Buoys."

The following is the estimate of the amount of work still required for the improvement of Wareham Harbor, as far as present interests will justify:

Dredging on upper bar and vicinity, 24,107 cubic yards, at 35 cents	$8,437 45
Dredging opposite Barney's Point, 1,401 cubic yards, at 35 cents	490 35
Dredging Quahaug Bar and vicinity, 15,678 cubic yards, at 35 cents	5,487 30
Removal of rocks at Four Buoys, (approximate)	3,000 00
Engineering and contingencies	2,584 90
	20,000 00
Amount on hand, (appropriation approved June 23, 1874)	$10,000 00
Amount required in addition	10,000 00

It is proposed to do this work by contract. Wareham is the center of an iron-manufacturing business, using a large quantity of iron and coal, nearly all of which is brought in through this channel.

This harbor is a port of delivery. It is in the New Bedford collection-district, and New Bedford is the nearest port of entry. The amount of revenue collected there during the fiscal year ending June 30, 1874, was $21,095.47.

Financial statement.

Balance in Treasury of United States July 1, 1873	$15,000 00
Amount in hands of officer and subject to his check, (including $152.09 percentage due on contracts not yet completed)	2,251 03
Amount appropriated by act approved June 23, 1874	10,000 00
Amount expended during the fiscal year ending June 30, 1874	17,157 11
Amount available July 1, 1874	10,093 92
Amount required for the fiscal year ending June 30, 1876	10,000 00

Report of Mr. H. S. Van Ingen, Assistant Engineer.

ENGINEER OFFICE, UNITED STATES ARMY,
Newport, R. I., July 1, 1874.

GENERAL: I have the honor to submit the following report, with map of operations for the improvement of Wareham Harbor, Massachusetts, from April 1, 1873, to the end of the fiscal year ending June 30, 1874, prosecuted in accordance with acts of Congress approved June 10, 1872, and March 3, 1873, appropriating $10,000 each for this purpose.

Wareham is a town of about 3,000 inhabitants, scattered over a large section of country, and is the center of quite an important iron-manufacturing business. It is located at the head of Wareham Harbor, or River, which empties into the upper end of Buzzard's Bay. Next to New Bedford, it is the most important port approached through this bay. Within its limits are situated one rolling-mill and three nail-works in active operation, representing a capital of $630,000, and doing a business during the fiscal year ending June 30, 1873, of $1,190,000. During this time they received 37,647 tons of coal, iron, and other materials—all of this, except about 5,500 tons of coal, from the provinces—and a large part of their products passed through this harbor. The provincial coal used by the Tremont Nail Company, three miles distant, came in vessels drawing too much water for this place, and had to be landed at Fairhaven and brought thence to Tremont by rail at extra expense. The deepening and straightening of the channel in Wareham Harbor will render this unnecessary. A. S. Gurney & Co. do a grain and miscellaneous business of about $100,000 a year, entirely by water. These, in addition to the general merchandise business of the place, constitute the traffic interested in this improvement. The number of arrivals at this port in a year is about 225 vessels, all sailing up to the wharves. Before the late dredging there was often much delay in sailing up, but when the harbor shall have been thoroughly improved, it will be readily accomplished.

By your direction, I assumed charge of this work April 7, 1873, with instructions to make a detailed survey, and superintend the improvements. The maps in your possession were not sufficiently full to serve as a guide for practical work. From April 8 to 19 was spent in making an examination and so much of the survey of the harbor as

was necessary for the laying out of the work. I then returned to Newport and plotted the notes before the dredging was commenced. The survey was completed during the month of June while work was in progress.

The contract for dredging under the first appropriation was given July 30, 1872, to the lowest bidder, Mr. M. F. Brainard, of Albany, N. Y., at 34½ cents per cubic yard, he to commence October 1, 1872, and finish June 30, 1873. His dredge was stopped by you on the way to Wareham, and employed on special work until the spring of 1873, and his time for completion extended to September 1, 1873. The contract under the second appropriation was given to the same party May 6, 1873, for 36¾ cents, (the lowest bid,) work to be begun September 1, 1873, and completed June 30, 1874. Work under these contracts was commenced June 14, 1873, and prosecuted with due diligence until November 25, when the funds available for this purpose were expended. The survey made had developed the fact that not as much water by from 1 to 3 feet could be carried over the bars as was reported. The most important fact discovered, however, was the existence of a hard sand-ridge, with 5 feet of water on it at mean low-water, extending from the red buoy at Quahaug Bar to the point on the east shore, thus cutting off the connection between the deep water above and below it; the former maps had given a passage through this with 11½ feet of water at low-water. The channel used was very crooked, and not more than 7½ feet deep at mean low-water in the shoalest part. Instead, therefore, of straightening this or of making an entirely new one through the middle of Quahaug Bar, both of which plans were given in General Thom's last report on this work, I concluded, with your sanction, to make a cut through the ridge mentioned above. A channel, about 200 feet wide and 9 feet deep at mean low-water, was made, thus enabling vessels to take nearly a straight course, after turning the black buoys, up to Barney's Point. On the completion of this channel the straightening and deepening of the channel around and above the upper bar were carried on as long as the money allowed. A channel, 60 feet wide in its narrowest part, and 9 feet deep at mean low-water, was made from the town wharves down to the black buoy, and 6 cuts, 120 feet wide, were made around the point at this buoy. During the prosecution of dredging, a rock weighing 28 tons, too large to be moved by the dredge, was encountered opposite the Franconia Iron Works wharf. It was raised by means of a dump-scow, with chains passed through the wells and attached to bolts driven into it, and floated ashore at high-water.

The total amount of work done, and the expenditure therefor, are given below.

	Cubic yards.
Quahaug Bar (sand with mud at lower part)	21,862.27
Upper bar and thence to wharves, (mud, sand, and gravel)	24,901.00
	46 763.27

23,876.67 cubic yards, at 34½ cents per yard	$8,237 45
22,886.60 cubic yards, at 36¾ cents per yard	8,410 83
Removal of rock, 28 tons	154 00
	16,802 28

The estimates hitherto made on this work have been based on a greater depth of water than is really to be found on the bars of this harbor. They have been made, too, with a seeming preference for straight cuts through bars without regard to the configuration of the shores. This harbor consists of two bays joined by a narrow passage with another straight stretch above them. Below the lower one runs a sand-beach, bare at low-water, which limits the entrance to the west side of this bay. The beach is said to be in constant motion, and a comparison of the present one with former maps indicates that it is increasing in width. Whether the extreme point—which is the most important question—is extending west, cannot be determined. Opposite the village is a road bridge and a railroad bridge and embankment, with no draw, thus stopping the upward progress of vessels and contracting the water-way. The two passages through the bridges give a total width of 165 feet, about 20 feet deep at low-water. This is not as great an obstruction to the outflow through the harbor as would be supposed, from the fact that the narrowest cross-section of the straight portion opposite the wharves is only 200 feet wide and 8 feet deep at low-water; the depth of this, it is true, however, may be regulated by the water-way through the bridges. At the lower end of the wharves, this passage opens out at once into a broad bay, and the water hitherto running, while ebb, at a rapid velocity, is suddenly checked, and depositing its material forms the upper bar.

The cause of the formation of the lower or Quahaug Bar is quite different. The velocity of the current between the two bays is not great enough to transport any but the lightest material, and as a large portion of the bar is composed of sand, it must have come from other directions. Part may have been brought down Crooked River during freshets.

The boldness of the water inside Long Beach seems to indicate the reflection of the ebb-tide from its north shore, scouring out the sand and leaving it at the lower part of the bar, though the general direction of the ebb-current is across the bar. Without doubt, however, this is a "bulkhead bar," formed by the meeting of the ebb and flood tides, and in this respect distinct from the upper bar.

If the causes of these bars are still active, as supposed above from the configuration of the harbor, then no dredging improvements in the bars themselves can be permanent, and any straight cut through the body of them would rapidly fill up. The greatest advantage is to be derived from deepening them on the side next to the channel. The thorough improvement of this harbor would require the construction of dikes up to low-water mark through the two bays, so as to keep the water-way nearly of the same width from Wareham to Buzzard's Bay. The business of the place, however, does not authorize any such expensive improvement, and I therefore recommend that dredging be continued at the upper and lower bars, as indicated by heavy broken blue lines on the map accompanying this report; and further, that work on the upper bar be done first. The removal of rocks in Weweantic River, for which an estimate was formerly made, I consider uncalled for, as I could not find that the river is used at all. It is also quite independent of Wareham Harbor, and an appropriation for its improvement should be made specially for that purpose. Instead of it, however, I would recommend that a number of rocks below Long Beach, mainly at the Four Buoys, be taken out, as they are much in the way of vessels entering this harbor. No special examination has yet been made of them, as their removal should constitute the last improvement, and the estimate therefor is only approximate. I would suggest that a survey of them be made during the prosecution of improvements the next year.

The following is an estimate of the cost of future improvements:

Dredging on the upper bar and vicinity, 24,107 cubic yards, (mud, sand, and gravel,) at 35 cents per yard	$8,437 45
Dredging opposite Barney's Point, 1,401 cubic yards, (sand and mud,) at 35 cents per yard	490 35
Dredging in Quahaug Bar and vicinity, 15,678 cubic yards, (mud and sand,) at 35 cents per yard	5,487 30
Removal of rocks	3,000 00
Engineering expenses and contingencies	2,584 90
	20,000 00

There accompanies this report a map of Wareham Harbor, on a scale of $\frac{1}{4000}$, showing the location of dredging operations of the last year (shaded blue) and those proposed in the future, (indicated by heavy broken blue lines,) and two sheets of tide-observations kept in the spring of 1873. I was assisted in my survey at different times by Messrs. P. M. Blake and A. and W. B. Savary, assistant engineers.

Very respectfully,

H. S. VAN INGEN,
Civil Engineer.

General G. K. WARREN,
Major of Engineers, U. S. A.

X 4.

TAUNTON RIVER, MASSACHUSETTS.

At the date of my last annual report, August 30, 1873, the removal of bowlders from this river was in progress; it was continued until October 10, when the portion of the appropriation assigned to this purpose was expended; it has been productive of much good.

A contract for dredging, at $2 per cubic yard, had been made with Mr. E. R. Seward, of Albany, N. Y., he to begin June 1, 1873, and complete November 30, 1873. His contract was afterward extended to June 30, 1874, to allow him time to finish the work at Norwalk, Conn., under my charge, before beginning this. The dredging was diligently prosecuted from October 24 to November 26, 1873, and again from March 11 to March 31, 1874, when the appropriation was expended. The shoals known as Blake's Table Rock and Sheep Pen were thoroughly removed,

and a cut about 25 feet wide and 600 feet long was made through Chabbot Rock Shoal, the depth of each being 9 feet at mean high-water. The following is the amount of work done:

	Cubic yards.
Material dredged	3,443.42
Rocks and stones removed	224.50

On the completion of work a survey was made of the channel dredged and of several obstructions near Dighton, detailed examinations of which had never been made. The map of these surveys and a general map of the river, all on one sheet, are presented with the report of my assistant engineer, Mr. H. S. Van Ingen, who has been in charge of the operations on this river.

The future work contemplated is the removal of the remainder of the upper shoals by dredging and of the obstructions from Berkley bridge to Dighton, consisting of dredgeable materials and rocks.

The estimate for the whole improvement is somewhat increased over that of last year by the addition of the estimate for the shoals near Dighton, not before included, and for other minor reasons stated in the annexed report of my assistant.

Dredging, at $2 per cubic yard for upper shoals, and 50 cents for lower	$16,470 50
Removal of rock, at $8 per cubic yard	2,400 00
Engineering expenses and contingencies	3,129 50
Total	22,000 00
Less appropriation for fiscal year ending June 30, 1875	10,000 00
For year ending June 30, 1876	12,000 00

All of this could be advantageously expended in one year.

Taunton River is the channel for a very important navigation and business interest. It is in the Fall River collection-district, and that place is the nearest port of entry. The amount of revenue collected there in the fiscal year ending June 30, 1874, is $93,128.23.

Financial statement.

Balance in Treasury of United States July 1, 1873	$10,000 00
Amount in hands of officer and subject to his check	484 53
Amount appropriated by act approved June 23, 1874	10,000 00
Amount expended during the fiscal year ending June 30, 1874	10,387 58
Amount available July 1, 1874	10,096 95
Amount required for the fiscal year ending June 30, 1876	12,000 00

Report of Mr. H. S. Van Ingen, Assistant Engineer.

ENGINEER OFFICE, UNITED STATES ARMY,
Newport, R. I., July 1, 1874.

GENERAL: I have the honor to submit the following report, with map, of operations for the improvement of Taunton River, Massachusetts, for the fiscal year ending June 30, 1874, prosecuted in accordance with the act of Congress approved March 3, 1873, appropriating $10,000 for this purpose.

In fulfillment of the agreement previously made with them, Messrs. Staples & Phillips, of Taunton, Massachusetts, commenced the removal of rocks from this river July 7, 1873, and continued it until October 10 at the rate of $10 per cubic yard. The part of the appropriation assigned to this work having been then expended, operations were discontinued. During this time 224½ cubic yards were taken out, consisting of about 75 large rocks, and the remainder stones of various sizes; the largest rock removed weighed about 40 tons. They were taken from different points on the river between Blake's Wharf and the Needles, more than two-thirds from the latter point; these were in part left from the dredging of the Needles in 1871, some of the largest having been dug around but not removed, and others, mostly large stones, having been pushed by the dredge on the side ridges. These had greatly annoyed vessels and scows, especially in

swinging around the turn, and had given rise to the belief considered erroneous in my report of last year, that more dredging was required at the Needles. The amount of rocks and stones removed far exceeded my inspections, so that the money was gone before the Nook and other points further down the river were reached. The rocks were conglomerates and impure granites. The stones and small rocks were removed with the steam-engine of a pile-driver, lewis-bolts being driven into the rocks and tongs being placed around the stones. The large rocks were taken out in the following manner: Two dump-scows were joined by a king-post truss, from which heavy chains were suspended. A rock having been drilled and a lewis-bolt driven into the hole, the scows were placed over it at low-water, and the chains placed around the arrow-head of the bolt. As the tide rose the rock was lifted from its bed, the force due to the rise of the tide being assisted by large jack-screws supported by the truss; the rock was raised to the surface of the water by these means. At high-water the scows were hauled close to the shore and the rock deposited out of the way. Increased power was also obtained, in starting a rock from its bed, by partially filling the air-chambers of the scows with water before taking hold of the rock and pumping them out afterward. Many of the rocks and stones were placed on scows and carried to Taunton for wharf-fronts. The price paid insured the contractors reasonable profit.

A contract had been made with Mr. E. R. Seward, of Albany, New York, to dredge in Taunton River at $2 per cubic yard for all material removed, he to begin June 1, 1873, and complete the work November 30, 1873. This contract was afterward so changed as to allow him to begin on the completion of his work at Norwalk, Connecticut, under your charge, and to finish by June 30, 1874. The dredging was commenced October 24, and prosecuted with great diligence until November 26, when ice caused a cessation of operations. During this time the shoals known as Blake's, Table Rock, and Sheep Pen were removed, and the dredging of Chabbot Rock begun.

Operations were resumed March 11, 1874, and continued until the available funds were expended, March 31. A clear channel-way, 9 feet deep at mean high-water, and of the requisite width, according to location, was made through all these shoals, except the last; only one cut about 25 feet wide and 600 feet long could be afforded through this. The total amount of material removed is 3,443.42 cubic yards; it was much the same as that found in previous shoals, except that the rocks were less numerous; at the lower part of Chabbot Rock Shoal a very hard clay was met. All material except large rocks was dumped opposite Somerset; the rocks were placed well out of the way back from the channel, whence they will doubtless soon be removed for wharf-walls.

Notwithstanding the price was so much smaller than that paid for previous work, $5 per cubic yard in 1871 and $3.45 in 1872, good wages were made, because a stout and well-equipped dredge was used for the purpose.

While it cannot certainly be ascertained, except by an impracticable number of borings, how large a proportion of the remaining shoals consists of rocks, yet from the borings made they are judged to be of about the same composition as those previously removed, with a probability of a less number of rocks. The price allowed for future work, therefore, should not exceed $2 per cubic yard, and it can doubtless be done for somewhat less, though the difficulty of getting rid of the material will be the same.

On the completion of work in April, I made a survey of the channels dredged, of the shoal above Berkley Bridge and vicinity, of the obstructions at the Nook opposite Wickamount, and at Babbit's, now called Peter's Point, above Dighton, and of the shoal opposite Cobb's Wharf, at that village. These are points at which no detailed examinations had ever been conducted, and for the removal of which obstructions only approximate estimates had been made. The survey was completed April 14, and the map thereof accompanies this report.

Berkley Bridge, connecting the townships of Dighton and Berkley, has been rebuilt since my last report. The old one was removed some years ago, but the piers were never thoroughly taken away. The new bridge is a queen-post truss, with a Howe-truss draw 150 feet long. It rests on eight piers, including the pivot-pier. The width of each draw-span was intended to be 60 feet in the clear; it is that between stone-work, but the width available for vessels between fender-piling is about 50 feet. The pivot-pier is on the west side of the river, one end of the draw resting on the west abutment. The east draw-span is the only one open to navigation, and is best situated with reference to the direction of the channel above and below the bridge. The west draw-span is obstructed by the remains of an old pier, having 4½ to 5 feet of water over it at mean high-water. The deepest water above the bridge connects with this span, and there are doubtless times when it would be used by vessels in preference to the other one were it open. Below the bridge there is good water, and over 10 feet draught can be carried through the east draw-span at high-water; the depth then diminishes, and about 230 feet above a shoal of sand is encountered, having less than 9 feet of water over it at mean high-water; it is small, and above it the depth gradually increases to 10, 11, and 12 feet. This shoal may have been formed by the building of the old bridge, or it may be due to the increased width of the river at this point; there are no data to determine this.

At the Nook the obstructions consist of single rocks. The ebb-tide runs out through and over these almost in rapids, and with such velocity as to make it almost impossible to row a boat against it. A depth over 10 feet at mean high-water could be carried through this but for the numerous bowlders; no rocks were found which obstructed a channel-way 50 feet wide and 9 feet deep at mean high-water, though it is possible among the large number that such there may be. Still there are many rocks that need to be taken out, and, during their removal, any others will be readily found. The current sweeping around the point at the upper end of the Nook carries vessels, bound down, over to the east side among the rocks; this is especially the case with unloaded vessels and scows. There is good water close to this point, but not available on account of the "Fisher" rock and others; were these away, the tug could hug the point more closely, and keep the tow off the rocks on the east side. From the "Fisher" down to the red buoy at the lower end of the Nook there is a clear way. Here are numerous rocks, mainly on the west side, with from 6 to 9 feet of water over them at mean high-water; one, nearly in the middle, has just 9.1 feet on it, and possibly worse ones still may have been missed. These are very dangerous to navigation, and, not only this, they doubtless impede greatly the rise of the tide.

In the next turn below this, between Wickamount and the railroad bridge across the creek, is a shoal of gravel and sand, with an occasional bowlder. It is nearly in the middle of the river, in the angle formed by the confluence of the ebb currents from the river and creek. At mean high-water from 8½ to 9 feet draught can be carried over the actual bottom, though this is somewhat diminished by projecting rocks and stones. By keeping close to Wickamount it can be avoided, but the tendency of the current is to sweep vessels on to it.

From Wickamount to Peter's Point there is a good channel, with from 10 to 15 feet of water at high-water. The shores here are covered with bowlders, and the whole topography indicates rock formation. The east shore seems to be a continuous ledge, out-cropping on the extreme end of Peter's Point, dipping southwest. A projection of this forms Reuben's Island, and a rock 6 feet below high-water, between this island and the black buoy on the same range, was stated to be probably another out-crop of this by Lieutenant Quinn, United States Engineers, in his communication to Lieutenant-Colonel Thom, United States Engineers, dated September 5, 1871. I am not certain that I found the particular rock referred to by him, but as the locality is full of scattering bowlders, consider it quite as probable that the rock is of this character; experiment alone can determine this. My attention, however, was drawn especially by navigators of the river to that portion of the ledge on the extreme end of Peter's Point, and another out-crop 100 feet north, dipping west across the river. The ledge dips at such an angle as to give over a 10-foot draught of water from near the shore 150 feet out; this full width, however, is not available on account of the numerous projecting rocks, supposed by me to be bowlders; these limit the channel, 9 feet deep at mean high-water, to 65 feet in width. Farther west are several rocks with less water on them, while some in this contracted width have little water to spare over them. The removal of rocks at this point would, I think, render unnecessary any work between the black buoy and Reuben's Island.

From Peter's Point the depth continues from 10 to 15 feet at high-water, down below the red buoy, thence a shoal extends to the upper end of Cobb's Wharf, due to the sudden widening of the river here.

This completes the examination of the river from Taunton to Dighton. Between Dighton and Somerset is sufficient water, it is stated, to accommodate the wants of navigation, certainly as far as the city of Taunton is concerned, by the exertions of whose citizens the past appropriations have been obtained. In making the surveys of obstructions to navigation it has been my purpose mainly to determine whether they consist of dredgable material, or simply of rocks; if of the former, to obtain data sufficient to estimate the cost of their removal; if of the latter, to ascertain their general location and number, and to determine whether they are bowlders or parts of ledges. To have examined and located each rock in this river, where they are so numerous, would have taken too much time, without commensurate advantages.

The following is a summary of the work accomplished during the past year, and of the expenditures therefor:

Rocks, 224½ cubic yards, at $10	$2,245 00
Material dredged, (sand, gravel, clay, and rocks,) 3,443$\frac{43}{1000}$ cubic yards, at $2 per cubic yard	6,886 84
Total	9,131 84

A description of the manner in which the navigation of the Taunton River between Dighton and Taunton is conducted, is necessary to an understanding of the needs of the river and the best plan for future operations. Vessels are almost invariably towed up and down, four tow-boats being employed in this business. The steamers with their vessels and scows start from Dighton as soon after the flood-tide has made, as

they can cross the shoals and rocks at the lower part of the river; this they cannot now do more than about one hour before high-water at Dighton; they then reach the upper shoals a little before high-water, and on arriving at Weir must quickly break up one tow and reform a new one; by this time the tide is about turning at Weir and has been running out at Dighton for nearly three-quarters of an hour. The tow has good water over the upper shoals, but by the time the obstructions nearer Dighton are reached the tide has fallen very rapidly. As none of the tow-boats draw over 7 feet, they can pass over the rocks and shoals, and as vessels outward-bound are usually unloaded or lightly loaded, the tows succeed in getting out, though often only by dragging over the obstructions. But when a tug carries up a vessel drawing all the water available on the upper shoals, being detained later at the lower ones, she does not reach the upper ones till the last of high-water slack; then if the same tug has a loaded vessel to take out, they are late for even the upper shoals, and very late for those near Dighton, as the tide will have fallen about 2 feet when that place is reached.

I have gone thus into detail to show that a 9-foot depth of water over each shoal, at its respective high-water, is not equivalent to affording vessels a 9-foot draught from Dighton to Taunton and back. If the upper shoals be removed to 9 feet below mean high-water, then the obstructions from Berkley Bridge down to Dighton should be cleared away to a depth of 10 feet at least at the same stage of tide. The estimates that follow are based on this view of the matter, and their increase over the partially approximate ones of last year, before detailed surveys had been made, is due to this change and to the possession of more accurate data. The increase of the estimates for the removal of the upper shoals arises from the fact that it has been found impossible to dredge these to 9 feet depth, removing all rocks, without going at least 1 foot below this, so that to give a 9-foot draught at mean high-water allowance must be made to dredge to 10 feet.

The following is an estimate of the cost of future improvements, and includes, I think, all the work needed to be done between Dighton and Taunton to enable vessels to carry 9 feet between these places at mean high-water. The proposed dredging is shown on the accompanying map by heavy broken blue lines:

(1.) Chabbot Rock Shoal, to complete three cuts, 61 feet wide and 9 feet deep at mean high-water, 3,217 cubic yards, (sand, gravel, clay, and rocks,) at $2 per cubic yard	$6,434 00
(2.) "The Brothers" Shoal, to make three cuts, same as above, 1,803 cubic yards, (sand, gravel, clay, and rocks,) at $2 per cubic yard	3,606 00
(3.) John R.'s Shoal, to make two cuts, 43 feet wide and 9 feet deep at mean high-water, 552 cubic yards, (sand, gravel, clay, and rocks,) at $2 per cubic yard	1,104 00
(4.) Points between Chabbot Rock and Phillips's wharf, so as to give a channel 43 feet wide and 9 feet deep at mean high-water, 1,353 cubic yards, (sand, gravel, clay, and rocks,) at $2 per cubic yard	2,700 00
(5.) Removal of scattering rocks from the wharf below the Needles down to Dighton, especially in the Nook and opposite Peter's Point, so as to give a 10-foot draught of water at mean high-water, 300 cubic yards, at $8 per cubic yard	2,400 00
(6.) Cobb's Wharf Shoal, dredging a channel 80 feet wide, 10 feet deep, at mean high-water, 1,407 cubic yards, (sand,) at 50 cents	703 50
(7.) Wickamount, dredging out of shoal 10 feet deep at mean high-water, 1,835 cubic yards, (sand and gravel,) at 50 cents	917 50
(8.) Berkley Bridge, dredging three cuts 65 feet wide and 10 feet deep at mean high-water, 1,675 cubic yards, at 50 cents	837 50
Removal of old pier in west draw-span to 10 feet deep at mean high-water, 81 cubic yards, at $2	162 00
Total	18,870 50
Engineering expenses and contingencies	3,129 50
Total cost of improvements	20,000 00

These estimates are made in the order in which the obstructions to which they relate should be removed. The fourth one, for the removal of points between Chabbot Rock and Phillips's wharf, was not made last year because 8½ to 9 feet at mean high-water could be carried over them, and it was hoped that the removal of rocks and the increased rise of tide resulting from the clearing away of the obstructions lower down the river would render work at these points unnecessary. It is now included in the list in order that these estimates may be comprehensive of contingencies, it being placed last among the up-river improvements.

I would recommend that the $10,000 appropriated for the next fiscal year should be expended entirely in dredging and be applied to the removal of Chabbot Rock Shoal,

and the making of two cuts through "The Brothers" Shoal. According to the above estimates, at $2 per cubic yard, this, with contingencies, would just about exhaust the appropriation. Should the price bid be less, I would suggest that the balance of the appropriation be used in removing John R.'s Shoal, leaving the third cut through "The Brothers" Shoal to be made the following year.

There accompanies this report a map in one sheet on a scale of $\frac{1}{12000}$, showing (1) the points at which dredging has been done during the past year, (shaded blue,) and where it is contemplated in the future, (indicated by heavy broken blue lines;) (2) the portion of the river in the vicinity of Berkley Bridge, showing the shoal above it; (3) the river between the upper part of the Nook and Cobb's wharf at Dighton, with the different obstructions needing removal and referred to above; (4) an index map of Taunton River, Taunton to Somerset, on a scale of $\frac{1}{24000}$, showing the relative positions of the map, and also the localities from which rocks were removed during last summer, (cross-lined in blue;) (5) a side elevation of Berkley Bridge with a profile of the river bottom on its axis, on a scale of $\frac{1}{240}$.

I was assisted in the survey by Messrs. F. N. Lincoln and P. M. Blake, civil engineers.

Very respectfully,

H. S. VAN INGEN,
Civil Engineer.

General G. K. WARREN,
Major of Engineers, U. S. A.

X 5.

IMPROVEMENT OF FALL RIVER HARBOR, MASSACHUSETTS.

The act of Congress approved June 23, 1874, appropriated $10,000 for the removal of bowlders from this harbor. It is proposed to expend this in the removal of bowlders by contract after advertising in the usual manner.

The work will probably be done this autumn and the following spring.

The whole estimate for the improvements at this place was $45,000. The present appropriation will probably enable us to remove most of the bowlders, leaving the dredging and putting in dolphins to mark the channel till further means are provided.

It would be most economical to have all the rest of the estimate ($35,000) at one time, and it could all be advantageously expended in one year. The full value of removing the bowlders will not be realized until the whole work is done.

Fall River is in the Fall River collection-district, and is a port of entry. The revenue collected during the fiscal year ending June 30, 1874, was $93,128.23.

Financial statement.

Amount appropriated by act approved June 23, 1874	$10,000
Amount available July 1, 1874	10,000
Amount required for the fiscal year ending June 30, 1876	35,000

X 6.

NEWPORT HARBOR, RHODE ISLAND.

The work, under the appropriation of $8,500, made March 3, 1873, was commenced on the shoal lying between Lime Rock light and Goat Island, where the water was about 12 feet deep at mean low-water. Two cuts, giving a width of 50 feet, were made through this to a depth of 15 feet at mean low-water. The dredging was difficult, as the shoal

seems to be composed of glacial drift overlying the slate rock, not far below, fresh detached pieces of which were dredged up. These difficulties caused us to suspend operations there, and remove to the point of a sand shoal at the end of Goat Island. This was dredged off to a depth of 12 feet at mean low-water, and in such a line that vessels after passing the black buoy can take a direct course for Long Wharf without grounding. A jetty was also built, about 150 feet long, running out southwesterly from Goat Island, so as to arrest the sand moved along the shore, and prevent the point dredged off from being again extended.

None of the material dredged was suitable for the parapets or traverses at Fort Adams.

The inner harbor is now so shoal at the usual anchorage and approaches that it is proposed to expend the recent appropriation of $10,000 in deepening it here, where most necessary. The remainder of the first appropriation will be similarly applied, a small portion being reserved for taking care of the jetty, and repairing any breaches that may take place. I transmit with my report that of Mr. Cotton, who superintended the improvement.

Newport is in Newport collection-district, and is a port of entry. The amount of revenue collected during the fiscal year ending June 30, 1874, was $2,514.94.

Financial statement.

Balance in Treasury of United States July 1, 1873	$8,500 00
Amount appropriated by act approved June 23, 1874	10,000 00
Amount expended during the fiscal year ending June 30, 1874	7,555 81
Amount available July 1, 1874	10,944 19
Amount required for the fiscal year ending June 30, 1876	15,000 00

Report of Mr. J. P. Cotton, Assistant Engineer.

ENGINEER OFFICE, UNITED STATES ARMY,
Newport, R. I., June 30, 1874.

GENERAL: I have the honor to submit the following detailed report of operations for the improvement of Newport Harbor, Rhode Island, during the last fiscal year.

In November, 1873, a dredge was employed by the day in deepening to 15 feet at mean low-water the shoal between Lime Rock and the south end of Goat Island, where the depth was from 11 to 13 feet at the same time of tide. When the survey of the harbor was made in 1872 this bar was thought to be sand and gravel, but when we dredged it we found it to be of gravel, pebbles, and small bowlders, and so hard that but slow progress could be made. In the shoalest part of this reef, and about midway between deep water on either side, pieces of slaty rock were dredged that appeared to have been broken from rock in place. After passing the shoalest part of the ridge in coming into the harbor, the material grew finer, until sand and mud were reached at about 14 feet depth.

Dredging was continued on this reef through November, when, on account of rough weather, work was discontinued.

Work was resumed here in April, 1874, but after five days the dredge was transferred to the point of the shoal southeast of Goat Island, where she continued until the close of the work, May 20. The depth was increased from 9 and 10 feet to 12 feet. This shoal is composed of gravel, sand, and mud, with shells in each, met in the order named in coming into the harbor. It was thought that sand sufficiently clean for covering in the magazines at Fort Adams would be found in this bar, but none was found that would answer the purpose.

Work on the jetty at the south end of Goat Island was commenced on the 19th of May. The stone was quarried at Fort Adams and towed to the work in scows. The jetty was completed on the 19th of June. It is triangular in section, commencing on the shore above highest tide, and runs out about 150 feet to where there is about 1 foot of water at mean low-water. Its height is about 3 feet above mean high-water. The object of this jetty is to arrest the sand that is driven by waves along the west shore

of Goat Island, and which, if not stopped, would go to increase the bar, the point of which we have dredged off. If this answers the purpose for which it was built, others should be built along the shore of the island to the north. These stop the erosion of the island, and the sand that would find lodgment behind them would add to the area of the island.

The result of the work done on this improvement is, on the shoal between Goat Island and Lime Rock, not as great as was anticipated, because the material proved so much more difficult to dredge than was anticipated, therefore a less amount was removed. A channel about 50 feet wide and 16 feet deep was made. An increase of depth at this point is very desirable, as in extreme low-tides the large steamers of the Narragansett Steamship Company touch bottom if not in the deepest part of entrance, and this is often difficult to do in thick weather. The nature of the material shows that the tidal action would be sufficient to keep the channel clear if once opened, and increase of section here would probably increase both flood and ebb currents through the harbor.

The dredging off of the point at the southeast end of Goat Island affords relief to vessels entering the harbor, in that they can now haul up for the west end of Long Wharf as soon as they pass the buoy, and carry 12 feet at mean low-water into the harbor on this range, which before they could not do. That this was a serious obstruction is shown by the copper sheathing dredged from the different parts of the shoals. The jetty is built, but we shall have to await the action of the storms of autumn and winter to determine its efficiency. If it stops the drifting sand, the point of the bar off the island may be further dredged with good results.

The future improvement of this harbor should be in widening the channel through the reef at the entrance, and in dredging a channel from the deep water in the harbor into the harbor line. The latter will afford the greater present benefit, and I would recommend that the appropriation of $10,000, made by act approved June 23, be expended in dredging a channel 200 feet wide and 13 feet deep at mean low-water, where the present ruling depth is from 9 to 10 feet at the same time of tide.

Wharves are being built, and considerable dredging has been done by private parties since the improvement of the harbor was commenced, and if completed as estimated for much benefit will be realized.

The sum of $15,000 could be expended to advantage during the fiscal year ending June 30, 1876.

Mr. C. R. Mather, civil engineer, superintended the building of the jetty, and Mr. F. U. Lincoln, civil engineer, the dredging operations.

Respectfully submitted.

J. P. COTTON,
Civil Engineer.

Gen. G. K. WARREN,
Major of Engineers, U. S. A.

X 7.

PAWTUCKET (SEEKONK) RIVER, RHODE ISLAND.

During the fiscal year the work here was confined to a careful survey of the portion of the river heretofore dredged, and of the bridges that have been erected on it. I forwarded a report of this on the 6th of May, calling attention to the necessity for some legislative action or other control by the General Government, in order to remedy the injury caused to navigation by bad bridges. This was transmitted to Congress and printed as H. Ex. Doc. No. 264, first session, forty-third Congress. So far as I am aware no action in regard to the matter was taken.

Since that report was made by me the legislature of Rhode Island has authorized another bridge across the river in its navigable part, and I know of no way that I can officially act to prevent the parties from doing as they please in regard to its location, nor prevent their needlessly obstructing the channel until after they begin the work.

The appropriation on hand will be used to deepen and widen the channel at the shoal places, and in removing the stone from the east draw-opening of the Red Bridge.

I submit herewith the report of Assistant H. A. Bentley, assistant engineer, on the past improvement and present condition of the Paw-

tucket (Seekonk) River, Rhode Island. This report is accompanied by a map made from a survey conducted during the season of 1873. It is on a scale of 200 feet to the inch, and shows not only the condition of the channel, but also the positions and structure of the bridges across it. To these latter I wish to ask special attention. Mr. Bentley's report is as concise as the matter it contains will admit. There is, first, a history of the former improvements; second, an account of this last survey; third, a presentation of the points where further dredging is most needed; fourth, a history of the building and rebuilding of the bridges, and the legal authority for building them; fifth, a consideration of the obstruction these bridges cause to the tidal currents, and their influence in decreasing the height of the tide at the city of Pawtucket wharves; sixth, future improvements at bridges.

The points for special notice brought out under these different heads are as follows:

First, in regard to dredging already done. The dredging done previous to the last appropriation—that of $10,000, approved March 3, 1873—had made a channel-way 75 feet wide and 7 feet deep at mean low-water. It had been conducted under four different appropriations, and with the last one it was found necessary to redredge at places which had become filled since the first dredging. One object of the survey was, therefore, to determine the places where liability to re-form shoals existed, so that by making enlarged and deeper channels at these places we might secure the requisite draught, even after considerable refilling has taken place. Mr. Bentley's report clearly points out these; and if our future operations are to be confined to dredging, as they have been, I would recommend simply carrying out his suggestions with the funds now on hand.

But if something can be done at the bridges, I think it more important that it should be done there than altogether confined to the shoals above them. Before recommending that the last appropriation should be expended for this purpose, I would like to know what can be exacted from the bridge company. I beg here to refer directly to Mr. Bentley's report, page 14, "on the bridges." Their history and condition, the authority for printing them, and what should be done, are stated fully. At the Red Bridge, an expenditure of about $675 is required to remove stone from the east opening of the pivot-draw. It is now so obstructed that it is useless to navigation; and if the other draw-opening should be closed by a sunken vessel, all navigation of the river would be suspended. If the bridge company cannot legally be compelled to open properly this east draw-space, I would recommend that the present appropriation be used for that purpose. Under the heading "obstructions to tidal flow," &c., Mr. Bentley makes further estimates for dredging between the piers of the Red and Washington bridges, at an estimated cost of $8,085. This latter expenditure the means in our hands would not justify us in making, as it would prevent necessary dredging on the shoals above. I wish it would be ascertained, by proper reference, whether there is not legal remedy to compel this bridgecompany to restore the water-way to a proper natural width.

The Washington Bridge is in so bad a condition that it is expected to soon rebuild it; but it is a very serious obstruction to navigation, and it is not at all likely that, when rebuilt, it will be suited to the wants of navigation, unless some control is exercised over it by the General Government. The present railroad bridge might have been, and should have been, better located.

I deem it, therefore, a matter of importance that some steps should

be taken—what ones exactly, I do not know—to control the bridging of the Pawtucket River in the interest of navigation; and unless such control is acquired by the General Government, it seems to me out of place to further regard the improvement of the Pawtucket River as a public one, or that that estuary is longer a navigable water of the United States.

A small sketch in Mr. Bentley's report shows the location of the bridges

No further appropriation is recommended.

Pawtucket River is in the Providence collection-district. Providence is the nearest port of entry. The amount of revenue collected there during the fiscal year ending June 30, 1874, was $184,197.37.

Financial statement.

Balance in Treasury of United States July 1, 1873	$10,000 00
Amount expended during the fiscal year ending June 30, 1874	686 55
Amount available July 1, 1874	9,313 45

Report of H. A. Bentley, Assistant Engineer.

ENGINEER OFFICE, UNITED STATES ARMY,
Newport, R. I., April 4, 1874.

GENERAL: I have the honor to submit the following report on the improvement of the Pawtucket or Seekonk River, Rhode Island. This will be a history of improvement prior to 1873, an account of the survey in 1873, a description of shoals requiring dredging, a history and description of the bridges, and their effects on navigation and tides, with a statement of improvements required.

HISTORY OF IMPROVEMENTS.

The first appropriation for the improvement of this river was made in 1867, when $17,000 was allotted for the work. The money was expended in dredging the channel above High Hill, with the purpose of making it 75 feet wide, and 6 feet deep at mean low-water. The general depth in the channel of the river above High Hill, at this time, was 5 feet at mean low-water. The dredging done was at the bars known as High Hill Bar, Swan Point Bar, and Ingrahamville Bar. This improvement was carried on under Col. D. C. Houston, Major United States Engineers.

By act of Congress approved July 11, 1870, an additional appropriation of $8,000 was made for this improvement. This money was expended, under your direction, in making a channel 75 feet wide and 7 feet deep at mean low-water from Thornton's wharf, Pawtucket, to Bass Rock. The depth of water to be made was changed from 6 to 7 feet, because of the impracticability of making so light a cut as a depth of 6 feet required.

By act of Congress approved March 3, 1871, $7,000 was appropriated for the continuance of the improvement; this money was expended in connecting the channels dug in 1867 at High Hill and Swan Point, by dredging a channel 75 feet wide and 7 feet deep between them, and in dredging the bar immediately above Swan Point. An examination of the channels dredged in 1867 proved that the general depth in them was 7 feet at mean low-water, so that the dredging done in 1871 opened a channel of the required width and depth up to a point half way between Swan Point and Bishop's Point. A report, giving the details of the work done from 1870 to 1872 may be found in Report of Chief of Engineers for 1872, page 818.

By act of Congress approved June 10, 1872, an appropriation of $10,000 was made for this river. After the usual advertisements for bids, a contract was made with Mr. E. M. Payn, of Albany, N. Y., for dredging and removing material, at the rate of 32½ cents per cubic yard. Dredging was commenced under this contract August 8, 1872, at the place where work was stopped the previous year on account of the exhaustion of the appropriation.

The general plan adopted for the work was to continue the channel 75 feet wide and 7 feet deep up to Dunnell's wharf, there to connect with the channel dredged under the appropriation of 1870.

It was found necessary to redredge a greater portion of the channel opposite Ingrahamville, that had been dredged in 1867; also the bar at Dunnell's wharf; the latter place had filled in since 1871. Some dredging was also done on the bar opposite High Hill. This contract was completed May 12, 1873, 26,073 cubic yards of sand, gravel, and mud having been removed from the channel and placed on the adjoining flats.

By an act of Congress approved March 3, 1873, another appropriation of $10,000 was made for this work. The previous appropriations were supposed to have given the channel the required width and depth; it was, therefore, decided by you to have a survey made of the river, to ascertain how the available money might be expended, so as to give the greatest benefit possible to navigation.

SURVEY IN 1873.

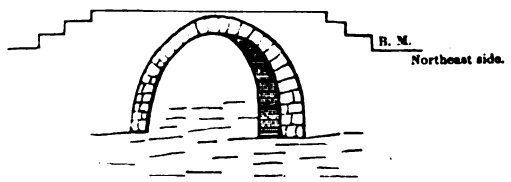
In pursuance of instructions received, I proceeded to Pawtucket May 14, and commenced the survey by covering the entire river, from Pawtucket to Fox Point, Providence, with a system of triangles, in which each angle was measured three times. A connection was made with the survey of Providence River made in 1872. The surveying party was then organized, and commenced the traverse May 19, starting at S. Grant & Co.'s old coal-dock, and running down the west bank of the river to India Point wharves, Providence, where the party crossed the river. A line was then run up the east bank from Station D, Providence River survey, to Clapp's chemical works, Pawtucket. The traverse lines were connected with the primary triangulation points, either by deflection and distance, or by making them stations of the line. The total length of traverse line run was about ten miles.

On the 2d of June the party commenced locating soundings. The position of each sounding was fixed by two angles, read from triangulation-stations which formed the ends of a known base.

The soundings were taken mostly in the channel of the river, the flats on either side being of so uniform a depth that but few soundings were necessary to give a true showing of them.

Each of the three bridges crossing the river was surveyed, data being obtained for elevations of them. Soundings were carefully located on their axes and around each pier.

Tidal observations were made for a lunar month previous to the survey, to establish a mean low-water plane; these observations were made at Butler Hospital Dock, from April 22 to May 19, inclusive, day-tides only being observed. The mean rise and fall of tide during that month was 4.46 feet. Mean low-water plane established by these observations is referred to a bench-mark on stone arch over road leading back from the wharf, and about 300 feet from it. This bench-mark is 55.794 feet above mean low-water. Below is a sketch showing its location.



Tide-gauges were established at Smith's wharf, Dunnell's wharf, Bishop's Point, Red Bridge, and Washington Bridge, for the reduction of soundings made in their vicinity. The zeros of these gauges were referred to the plane of mean low-water, as established at Butler Hospital Dock, by making simultaneous observations at the gauges at low-water, and assuming that the low-water at each of them bore the same relation to mean low-water that it did at Butler Hospital Dock, the place where the mean low-water plane was established.

Observations at Providence, extending from May 22 to December 28, 1873, were obtained from a record kept by the Providence City Water-Works. The mean rise and fall of tide during this time was 4.548 feet, or 0.088 foot more than that given by the observations at Butler Hospital Dock for one month only. This slight difference would show that the latter observations were taken at a time when the river was only ordinarily affected by the winds or other disturbing influences.

Observations to establish a mean low-water plane were made at Bishop's Point for a lunation in October and November, 1872. These observations give the mean rise and fall of tide as 5.04 feet, being 0.58 foot more than that given at Butler Hospital Dock, and 0.492 more than at Providence. The simultaneous observations taken show that the mean low-water here, as established in 1872, is 0.2 foot lower than that at Butler Hospital wharf. The probable cause of this difference is that the observations in 1872 were taken at a time when the prevailing winds very materially affected the tides, so that these observations do not show the state of the river, as it is at ordinary seasons, as well as those taken at Butler's Hospital Dock in 1873; and for this reason the latter plane was used for the reduction of soundings. Mean low-water at Bishop's Point is referred to a bench-mark on the point, which is a cross cut in the river-face of a boundary-stone, the intersection of the lines forming the cross being the mark. This

mark is 6.42 feet above the mean low-water plane established here in 1872, and 6.22 feet above the mean low-water plane established by simultaneous readings.

The observations at the above-mentioned places are appended to this report.

[The map of this survey, platted to a scale of 200 feet to the inch, on which are shown sections of bridges and profiles of river-bottom along their axes, is submitted herewith.]

SHOALS REQUIRING DREDGING.

From the map of the survey, it appears that the channel heretofore dredged and supposed to be 75 feet wide and 7 feet deep at mean low-water, is in some places considerably less than this in width and depth. These places, commencing in the upper part of the river, are Thornton's Bar, Dunnell's Bar, Bass Rock Bar, Swan Point Bar, and Butler Hospital Bar. The following is a short description of each, together with estimates for removing that part of them lying in the channel:

Thornton's Bar lies about 300 feet below Thornton's lower wharf. The 7-foot channel here is only 40 feet wide. It was dredged in 1871 to a width of 75 feet, but has since filled in. To redredge this to the required width would require the removal of 1,200 cubic yards of sand and gravel.

Dunnell's Bar is immediately below Dunnell's wharf. A channel has been dredged through this bar twice since 1870, and there is now less than the 75 feet width with the required depth of 7 feet at mean low-water. The formation of this bar is probably due to the fact that the river, which above this point is confined to a comparatively narrow channel, here expands to nearly double its former low-water area. The ebb tide in that part of the river above this bar is quite strong, and probably brings down a large amount of material, of which a large proportion is deposited at this place because of the sudden decrease in the velocity of the current caused by the increase in section. It is recommended that the dredging be carried to 9 feet at mean low-water at this place, in order to give an improvement that may at least last for a few years. This, it is estimated, will require the removal of 1,800 cubic yards of sand and gravel.

Bass Rock Bar.—The removal of 500 cubic yards of sand and gravel will be sufficient to give the required width and depth to the channel here, as it only needs dredging for a short distance on the east side, immediately below Bass Rock.

Swan Point Bar.—This is the most troublesome shoal in the river. The channel, running nearly straight for a mile and a half above, here makes a turn to the right, at an angle of about 45°. The effect of this turn is to form an eddy, which probably deposits the material forming the bar. It is recommended that this bar be dredged to a depth of 9 feet at mean low-water. For a distance of about 1,500 feet below this shoal the channel needs widening in several places. The removal of 11,000 cubic yards of sand and mud is estimated as being necessary for the improvements at this locality.

Butler Hospital-wharf Bar.—This is the last shoal in the river obstructing the channel, 75 feet wide and 7 feet deep, between Providence and Pawtucket. A small amount of dredging is needed here to widen the channel just below the hospital wharf, on the west side of the channel. The removal of 500 cubic yards of mud will give the required width.

In addition to these improvements, I would recommend that the channel of the river between Thornton's wharf and Smith's wharf be widened from 75 feet to 140 feet, because of the close proximity of the channel here to the wharves. Vessels unloading at Thornton's wharf obstruct the channel so much that it is almost impossible for other boats to get by them. This improvement, it is estimated, would require the removal of 3,000 cubic yards of sand and gravel. It includes the removal of a small point extending into the channel opposite Thornton's lower wharf.

The following is a summary of dredging required, with its estimated cost:

Thornton's Bar, 1,200 cubic yards sand and gravel.
Dunnell's Bar, 1,800 cubic yards sand and gravel.
Bass Rock Bar, 500 cubic yards sand and gravel.
Swan Point Bar, 11,000 cubic yards sand and mud.
Butler Hospital Wharf, 500 cubic yards mud.
Thornton & Smith's Bar, 3,000 cubic yards sand and gravel.

Eighteen thousand yards, at 33 cents per yard, would cost $5,940; add 10 per cent. for engineering and contingencies gives the total cost $6,534.

THE BRIDGES.

There are three bridges crossing the river. The first, or upper bridge, is known as the Red or Central Bridge; the second, about three-fourths of a mile below, as the Washington Bridge; and the last, about 250 feet below this, as the India Point Railroad Bridge. The first two are highway bridges.

The following is a brief history of each of them from the time of their first being built:

Red or Central Bridge.—The first bridge at this location was built in 1793. It was a wooden truss, resting on six pile-piers, and having a draw-span on the west side, with

one opening 24 feet in length. It was carried away by a gale in 1807, and was rebuilt in the same year.

The piles on which the former superstructure rested having decayed so as to be unsafe, piers of rubble masonry were built around them.

In 1859 the general assembly of the State of Rhode Island passed an act requiring the draw-openings in the bridges over the Seekonk River to be made 38 feet wide in the clear. The draw of this bridge was widened in accordance with this law.

The entire bridge was rebuilt in 1871, the draw being located in the center, with spans of 80 feet in the clear on either side of the pivot-pier, the ends of the span resting on stone piers, which are connected with the shore by spans 88.92 feet long. The piers are built of laid masonry, resting on the foundations of the old piers, except the pivot-pier, which rests on a pile foundation. The superstructure is of iron.

The building of this bridge was authorized by an act of the State assembly of Rhode Island, passed May 28, 1869. Section 2 of this act, in relation to draw in said bridge, says:

"To have a draw-bridge of not less than 80 feet in width on each side of said draw when opened, and located in the main navigable channel of the river for the safe and convenient passage of all vessels navigating said river through said draw."

The draw of this bridge was not located in strict accordance with this law, the then main navigable channel of the river being on the west side where the old draw-span was located.

The present openings of the draw are nearly in a line connecting the deep water above and below the bridge, so that passing vessels can straighten out before entering the bridge, and for this reason the draws as now located are an improvement on the location as provided by the law just quoted.

These draw-openings are probably in what was the main channel of the river; but to protect the piers of the old bridge a large amount of stone was thrown in about them from time to time, until the depth of water in that part of the river where the draw-spans now are was but 4 feet at mean low-water. When the present bridge was erected the west draw-opening was dredged to a depth of 10 feet at mean low-water; the east opening is still obstructed by riprap, and is useless to navigation.

If the draw-spans had been located in strict accordance with the law, and had the company done the same amount of dredging as they have done, we should have had two navigable draw-openings instead of one; of which the east opening would have been in the same location as the now navigable draw-span. If the present opening should in any way be obstructed, the navigation of this river must stop until such obstruction is removed.

The amount of material to be removed from the east opening to give 12 feet at mean low-water is about 350 cubic yards, which, at $1.75 per cubic yard, would cost $612.50: adding 10 per cent. for contingencies, gives the total cost $673.75. Inasmuch as the bridge company authorized the location of the draw in its present position, and also authorized the throwing in of the material forming the obstructions here, it would seem to devolve on them to bear the expense of dredging this material out.

The low-water area or axis of this bridge before piers were built was 3,752 square feet; the area occupied by foundations of old and foundations and piers of new bridge is about 2,462 square feet. The high-water area was 5,298 square feet; area occupied by piers, &c., 2,619 square feet.

Washington Bridge.—This bridge was built in 1793 on six pile-piers, with a draw, having one opening, 24 feet in length, on the east side of the river. This bridge was carried away by a storm in 1807, and was rebuilt in that same year. It was carried away again and rebuilt in 1815. At this time the three piers west of the draw were built up of rubble masonry in the same manner as was done in the Red Bridge. These piers settled, so as to be entirely out of sight before the new superstructure was ready to be put up. More riprap was thrown in on top of the submerged piers, and piers built on top of this. These piers stood until 1867, when one of them toppled over. This was supposed to have been caused by oystermen bringing up the stone forming the foundation of the pier while fishing about the bridge. This pier was rebuilt, and the three remaining pile-piers built up similar to the rest. About this time an act was passed by the general assembly prohibiting oyster-fishing within a certain number of feet of the bases of the piers.

The draw-opening of this bridge was increased to 38 feet about the year 1859, in accordance with the law to that effect.

The present superstructure is a wooden lattice truss, built on the rubble piers heretofore described. The draw-span is of the same length as in 1859, (38 feet.) The general depth of water in the draw-span is 6.6 feet at mean low-water; the greatest depth is 9 feet.

The low-water area on the axis of the bridge before the piers were built was about 3,697 square feet. The area occupied by the foundations and piers of the bridge is about 2,054 square feet. The high-water area was about 5,587 square feet. Area occupied by piers, &c., 2,586 square feet.

India Point Railroad-Bridge.—This bridge is about 250 feet below Washington Bridge. The first bridge built here in 1855 was located about 40 feet above the present one. It rested on three piers, composed of oak piles, covered with copper, to protect them from the "Terredo navalis." These piers lasted until 1857, when they had to be renewed; these in turn decayed, and in 1867 were substituted by the Cushing patent iron-cylinder pier, on which the present bridge rests.

The draw-openings of the old bridge were located on the east side of the river. The draw at first had but one opening. In 1858 a new draw was built, having two spans 38 feet wide in the clear.

The act authorizing the construction of the present bridge, built in 1867–'68, passed the general assembly in 1866. This act provided that the draw of the bridge should be at least 60 feet in width, and that the proposed bridge and draw should be located in a manner satisfactory to Robert Sherman, esq., of Pawtucket. The first condition has been carried out; as to the latter, I am not informed.

This bridge is 396½ feet long, divided into three spans and a draw. Commencing on the west side, there is first a span of 113 feet; next, one of 108½ feet; next is the draw, 154 feet, with openings of 60 feet in the clear; and last, a short span of 20¾ feet, one end of which rests on a stone pier, the only one in the bridge, the other end resting on the abutment. The superstructure is a Howe truss. The low-water area on axis of bridge before piers were built was 5,148 square feet; area occupied by piers, 683 square feet; high-water area was 6,849 square feet; area occupied by piers, &c., 873 square feet. The piers of this bridge, as regards economy of area obstructed by them, are as good as any that are used, and present a marked contrast with the piers of other bridges crossing this river.

An act in relation to this bridge, passed by the general assembly in 1868, says:

"SECTION 2. Said draw-tender shall at all times during the season of navigation cause the draw of said bridge to be opened for the passage of boats or vessels, on proper signals, to be arranged by said company; but the draw of said bridge shall not be opened within ten minutes of the table-time for the passing of any train or locomotive over the same until after the arrival and passing of any train due; and any boat or vessel ready to pass shall not be detained beyond the time provided for in this section."

"SEC. 4. Masters of vessels passing said draw shall so place their buoys, warping-lines, cables, or anchors as neither to interfere with other vessels nor obstruct the bridge, only as they may be authorized by the draw-tender, and without the consent of said draw-tender not more than one vessel at any one time shall be towed through said draw by any steam-tug or other motive-power."

The latter part of section 4 of this act gives to the draw-tender authority to regulate the size of all tows passing through this bridge, so that a man appointed draw-tender, while he may be utterly ignorant of all matters pertaining to navigation, can insist on the disposition of each tow in such a manner as to be a source of expense and trouble. I have never heard of any undue interference on the part of the draw-tender, and only mention this as a contingency.

To facilitate the passage of vessels through this and Washington Bridge, double lines of piling have been put in between the draws of the two bridges. This piling has been extended about 300 feet above Washington Bridge, and one line has been extended about the same distance below the railroad bridge. The space between these lines of piles varies from 38 to 60 feet. Vessels going up the river enter this passage at an angle with the current, and pass the railroad bridge at an angle of 20° with the axes of the piers. When they reach Washington Bridge, a turn must be made to the left of about 45°. This turn has to be in the draw of the bridge, where the passage is only 38 feet wide. These vessels pass up the river at high-water, when there is but little current. They cannot tow through safely, because of the sharp turn above alluded to, but have to warp through, and make up the tow above. In descending they generally leave Pawtucket after the tide commences to run out, and reach these bridges when the current is very swift, often as much as five miles per hour. To break up a tow in a current like this, so as to enable the vessels to warp through, would be attended with great danger of being carried down on to the bridge to the west of the draw. Their only course is to be taken through by the tug, and this must be done at a speed greater than the current, in order to keep steerage-way. In making this passage they are very frequently damaged by coming in contact with the piling. Once in the passage, there is no escape, except with the current at the lower end.

The city of Providence is now considering the advisability of erecting a new bridge on the site of Washington Bridge, for which the city engineer is preparing plans. It is designed making the draw-spans 60 feet wide. This new draw, if properly located and of sufficient width, will be of great benefit to navigation interests. To best serve these interests the new draw should be placed opposite the draw of the railroad bridge, in a line parallel with the general trend of the channel above as far as Twin Islands. The draw-spans should be 80 feet wide instead of 60 feet, because of the necessity of having fender-piling around the piers, which takes up from 10 to 15 feet of the availa-

ble space, as in the case of the railroad bridge, with a draw 60 feet wide and only 47 feet clear space between the piling.

This location of a draw would give descending tows the desired opportunity of straightening before entering the draw, and would also secure to them a straight passage through these draws. A sharp turn to the right would have to be made when free of the lower bridge. This, however, could be done with comparative safety. Vessels ascending the river would have no trouble in being towed directly through to Pawtucket. It is thought this is the best plan that can be adopted, with the draw of the railroad bridge located as it now is. Why this draw was located in its present position is not evident. It was probably the intention that only one draw-opening should be used, as the location of the east span so far from the channel precludes its ever being of any practical use. Had this draw been located 60 feet west of where it is, a draw-span much more favorable to the passage of vessels could have been selected in the proposed Washington Bridge, and we should also have had two navigable draw-openings in this (the railroad) bridge. The adjoining sketch shows the location of the bridges heretofore described, also the proposed passage-way between the two lower bridges.

OBSTRUCTIONS TO TIDAL FLOW AT BRIDGES AND IMPROVEMENTS REQUIRED THEREBY.

The amount of water brought into this river by its tributaries is very small, and wholly inadequate to keep open a channel of the depth sought for navigation. To the scouring power of the tidal flow alone we must look to keep open this channel, and this it fails fully to do. This being the case, it is important that everything obstructing the free flow of the tide, keeping out any portion of the water that would otherwise flow into the upper reaches of this basin, (where the effect as a scouring power would be most beneficial,) should be removed.

In selecting sites for bridging this river, the narrowest places were chosen, because of the economy of construction at these places, when compared with other parts of the river.

We thus have the Red Bridge, Washington Bridge, and the railroad-bridge at places where the natural section was but about half of the area of a section at any point of the river for a distance of three miles above the lower bridge.

In addition to this natural obstruction to the tidal flow we have the foundations and piers of the bridges, occupying a large portion of the already too small sectional area.

The area thus occupied by the Red Bridge at high-water is about 49 per cent.; at low-water, 66 per cent. At Washington Bridge, at high-water, the area occupied is 44 per cent.; at low-water it is about 55 per cent.; while at the railroad-bridge it is very small, only about 12 per cent.

The effect of these obstructions on the rate of tidal propagation in the river is very apparent, as the results obtained from the following tidal observations will show:

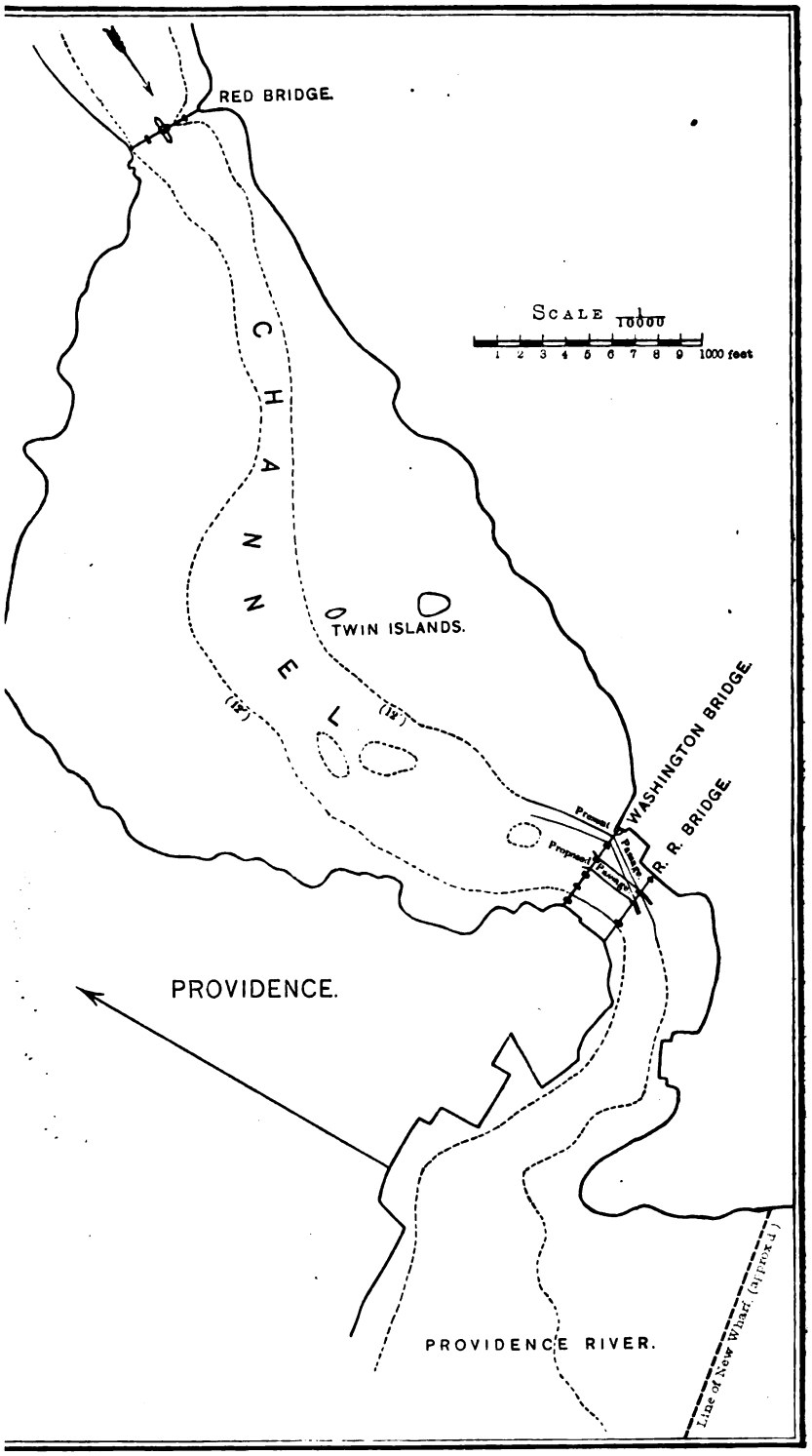
The tide-gauges at Washington and Red Bridges were located about 50 feet above the bridges. From the observations at these places, and those made at Hill's wharf, Providence River, and Butler Hospital wharf and Dunnell's wharf, Pawtucket River, the following comparisons are made:

The tide at Hill's wharf commenced to rise six minutes before it did at the gauge at Washington Bridge, twenty-one minutes before Red Bridge, thirty-six minutes before Butler Hospital wharf, and forty-six minutes before it did at Dunnell's wharf.

Now, the flood-tide should reach the gauge at Washington Bridge nearly at the same time it does Hill's wharf, because there is very little difference in the distance the tidal wave, coming up the Providence River, has to travel to reach each point. Taking this tidal wave as it travels farther up river, we find that it reaches the Red Bridge, a distance of about three-fourths of a mile, fifteen minutes after it was at Washington Bridge, having traveled at the rate of three miles per hour. It reaches Butler Hospital wharf fifteen minutes after it was at Red Bridge, traveling this distance (about one mile) at the rate of four miles per hour. In going from Butler Hospital wharf to Dunnell's wharf, a distance of about one and three-fourths miles, it takes only ten minutes, having traveled at the rate of ten and one-half miles per hour.

This comparison shows that in the upper part of the river, where there are no artificial obstructions, the rate of propagation is three times as fast as in the lower portion of the river, whereas if the sections at Red and Washington Bridges were equal to sections taken at any other part of the river between Butler wharf and Providence, we ought to have a rate of propagation exceeding that in the upper part of the river, because of the greater sectional area in this (the lower) part of the river. This increased area is due to the very much greater depth of water.

High-water does not get to Dunnell's wharf until 27 minutes after it has reached Providence. The duration of high-water stand is 15 minutes at Providence. Supposing the tide to travel at a uniform rate, the last of the flood-tide would only reach a point about half way between Providence and Dunnell's wharf when the tide at


RED BRIDGE.
SCALE 1/10000
1 2 3 4 5 6 7 8 9 1000 feet
CHANNEL
TWIN ISLANDS.
WASHINGTON BRIDGE.
R. R. BRIDGE.
PROVIDENCE.
PROVIDENCE RIVER.
Line of New Wharf (proposed)

Providence would have turned and be flowing in the opposite direction. It is evident, therefore, that the full effect of the tide does not reach Pawtucket.

In view of these facts, and inasmuch as this river is only navigable for loaded vessels at high-water, it would seem to be of the first importance to increase the sectional area at the Red and Washington Bridges, so as to facilitate the passage of the tide into the upper portions of the river, and thereby decrease the velocity of the current that now renders navigation at these places additionally precarious. At the railroad-bridge the obstruction is very small, and offers but little resistance to the tidal flow.

To restore the original section at Washington Bridge would require the removal of 2,300 cubic yards of material. At Red Bridge it would require the removal of 2,600 cubic yards. This material is riprap stone and shells. The riprap varies in size from an ordinary cobble-stone to stone weighing ¼ ton. It is estimated its removal would cost $1.50 per cubic yard; 4,900 cubic yards × $1.50 = $7,350 + 10 per cent. for engineering and contingencies, giving the total cost of removing both obstructions $8,085.

This work could be done with a small "Osgood" dredge. Nothing could be done at Washington Bridge until the present bridge structure is removed, as any dredging done near the piers would endanger the stability of the structure.

As to who should bear the expense of doing this work, it is not for me to say. That if done it would effect a more permanent improvement than the dredging of shoals, as estimated for on pages 5 and 6 of this report, I do not doubt.

If both could be accomplished the wants of the navigation interests of the river would be fully met. The estimated cost of both improvements is $14,619.

The number of vessels towed to Pawtucket during 1873 was 420, with cargoes consisting principally of coal and lumber.

The early history of the bridges I obtained from a pamphlet written on them by Col. J. Albert Monroe. I was assisted in the survey by Mr. W. P. Jewett, civil engineer. The work of dredging was under the direct superintendence of Mr. G. N. Weaver, civil engineer.

Respectfully submitted.

H. A. BENTLEY,
Civil Engineer.

Bvt. Maj. Gen. G. K. WARREN,
Major Engineers, U. S. A.

Record of tide-gauge kept at Hill's wharf, Providence, by the City Water-Works, from May 22 to December 28, 1873.

[The observations were taken with a self-registering tide-gauge, furnished by the United States Coast Survey.]

Date.	Number of high-waters.	Total high-waters.	Number of low-waters.	Total low-waters.	Notes.
May 22 to 31, 1873	17	139.51	18	57.86	
June 1 to 30, 1873	56	451.58	55	200.46	
July 1 to 31, 1873	60	486.23	60	216.95	
August 1 to 31, 1873	56	442.51	56	191.96	Two days lost.
September 1 to 30, 1873	58	467.20	58	197.97	
October 1 to 31, 1873	60	497.95	60	215.83	
November 1 to 30, 1873	58	455.23	58	192.59	
December 1 to 28, 1873	48	375.74	49	167.76	Four days lost.
Total	413	3,315.95	414	1,441.38	

1441.38 ÷ 414 = 3.481, mean low-water.
3315.95 ÷ 413 = 8.029, mean high-water.
8.029 — 3.481 = 4.548, mean rise and fall of tide.

Record of tide-gauge kept at Bishop's Point, Pawtucket River, Rhode Island, in October and November, 1872.

Date.	High-water.	Low-water.	Date.	High-water.	Low-water.
October 13	7.6	1.1	October 28	6.8	2.0
14	7.6	1.4	29	5.8	2.0
15	6.9	1.6	30	6.8	2.2
16	7.7	1.8	31	7.7	1.9
17	7.7	1.6	November 1	7.9	2.0
18	7.7	1.5	2	7.0	1.8
19	7.0	1.6	3	7.8	1.8
20	7.0	1.6	4	7.5	1.8
21	6.5	2.0	5	7.2	1.7
22	5.9	2.1	6	7.7	1.7
23	5.6	2.2	7	7.2	1.7
24	5.6	1.6	8	6.6	1.8
25	5.7	1.9	9	6.0	1.8
26	5.8	1.7	10	6.7	2.0
27	5.9	1.6			

Whole number of days' observations made, 29. Mean high-water, 6.85 on gauge; mean low-water, 1.81 on gauge; mean rise and fall, 5.04 feet. Lowest tide below mean low-water, 0.71 foot; highest tide above mean high-water, 1.05 feet.

Record of tide-gauge kept at Butler Hospital wharf, Pawtucket River, Rhode Island, in April and May, 1873.

Date.	High-water.	Low-water.	Date.	High-water	Low-water.
	Feet.	*Feet.*		*Feet.*	*Feet.*
April 22	5.5	1.0	May 6	4.6	0.9
23	5.7	0.5	7	4.9	1.1
24	6.2	0.3	8	5.0	0.8
25	5.7	0.1	9	5.25	0.8
26	5.6	0.0	10	4.9	1.1
27	5.6	0.1	11	5.3	0.6
28	5.3	0.05	12	5.5	0.8
29	5.5	0.4	13	5.6	1.1
30	5.4	0.1	14	4.8	0.8
May 1	4.2	0.3	15	5.4	0.9
2	4.5	0.9	16	5.1	0.85
3	4.8	1.0	17	5.2	1.0
4	4.8	0.7	18	4.6	1.3
5	4.1	0.6	19	4.7	0.7

Whole number of days' observations made, 28. Mean high-water, 5.13 on gauge; mean low-water, 0.67 on gauge; mean rise and fall, 4.46 feet. Lowest tide below mean low-water, 0.67; highest tide above mean high-water, 1.07.

X 8.

PROVIDENCE RIVER, RHODE ISLAND.

Operations under the act approved March 3, 1873, appropriating $10,000 for this work, were confined to the removal of the point of Long Bed.

The contractor commenced work early in July, 1873, and completed his contract in the latter part of September, having removed 30,529 cubic yards of material.

After the work of dredging was completed, an obstruction was found in the channel outside of where the work had been done. This obstruction, on examination, proved to be a clump of piles, cut off near the river-bottom. They were said to be the remains of an old dolphin placed there to mark the channel. These piles (twenty-one in all) were removed with a dredge and diver.

The improvements completed have given to the channel at this place

an additional width of 400 feet, making it 800 feet wide, and have straightened the 12 and 9 foot contours.

The estimate in my last annual report was for the removal of this point far enough back to straighten the 6-foot contour; but the work having cost 4 cents per cubic yard more than was estimated for, the money appropriated was not sufficient to complete the improvement I then recommended.

It is thought, however, that the work already done leaves this part of the river in as good condition as is necessary for the safety and convenience of commerce. No further appropriation is therefore asked for.

The work has been under the superintendence of Mr. H. A. Bentley, assistant engineer, whose report, giving in detail the plan of operations during the past year, is appended to mine.

Providence River is in the Providence collection-district, and Providence is the nearest port of entry.

The amount of revenue collected there during the fiscal year ending June 30, 1874, was $184,197.37.

Financial statement.

Balance in Treasury of United States July 1, 1873	$10,000 00
Amount in hands of officer, and subject to his check	178 24
Amount expended during the fiscal year ending June 30, 1874	10,101 26
Amount available July 1, 1874	76 98

Report of H. A. Bentley, Assistant Engineer.

ENGINEER OFFICE UNITED STATES ARMY,
Newport, R. I., June 30, 1874.

GENERAL: I have the honor to make the following report of operations for the removal of the point of Long Bed, Providence River, Rhode Island.

The survey of Providence River between Fox Point and Field's Point made in 1872, under your direction, by me, included the point of Long Bed. From the map of this survey an estimate was made for the removal of this point, so as to straighten all the contours between 12 and 6 feet. The estimate was for the removal of 40,000 cubic yards of material, to cost 25 cents per cubic yard, making a total of $10,000, not including the cost of superintendence, &c.

By act of Congress approved March 3, 1873, $10,000 was appropriated for this improvement.

Before issuing specifications for this work, borings were made to ascertain the character of the material. The borings were made with an iron rod which was driven to a depth of 20 feet below mean low-water. The material was found to be shells, gravel, and mud, closely packed.

After the usual advertisements, the work was let to Mr. S. F. Shelbourne, of New York City, for 29 cents per cubic yard. Mr. Shelbourne commenced work July 8, 1873, with a large clam-shell dredge, and during the month of July removed 10,102 yards; in August he removed 11,496 yards; and in September he removed 8,931 yards—making a total of 30,529 cubic yards.

The dredging done had straightened the 12 and 9 foot contour lines, and the balance of the appropriation being insufficient to make another cut, the work was stopped (September 25.)

The estimate for this work was for 25 cents per cubic yard, whereas it cost 29 cents, a difference of 4 cents per cubic yard, which on the estimated number of yards would amount to $1,600; this added to $10,000 (estimated cost), + $1,200 for superintendence, would give the cost $12,800. This amount, less $10,000, appropriated by act approved March 3, 1873, leaves $2,800 necessary to complete the improvement estimated for.

The improvement as completed is, I think, adequate to the wants of commerce here. But few vessels coming up this river are of a lighter draught than 10 feet when loaded; and if the channel was straightened to the 6-foot contour, my later experience here leads me to think that it would not be of sufficient practical value to warrant the expenditure of even the small amount of money necessary to do the work.

In the spring of 1874 complaint was made through the United States light-house inspector of this district that a clump of piles, cut off under water, had been left by the contractor.

An examination of that part of Long Bed dredged discovered no obstruction here; but, on extending the examination into the channel, a hummock was found with less than 12 feet of water on it, while there was a depth of 15 feet around it. This hummock proved to be a clump of piles cut off near the river-bottom. A dredge was employed and set at work digging around these piles. A diver was then sent down to fasten to the piles a chain which was lowered to him on the bucket of the dredge. The piles were then pulled singly by raising the bucket. In this manner twenty-one piles were taken out. These piles were driven so closely together that they had to be pried apart to fasten the chain. They are supposed to be remnants of an old dolphin put at this point to mark the channel, and had been cut off by the ice.

The dredge for this work was furnished by Mr. E. R. Seward, of Albany, N. Y. It cost $75 per day, and was employed three days. A steam-tug was also employed to tow the dredge into position, and to tow away scows; this cost $45. The diver and apparatus were furnished by Messrs S. Grant & Co., of Pawtucket, the cost of which was $85, making the total expense of removing the piles $355. This amount, added to $8, 853.41 expended under contract $9,208 41
The superintendence and cost 791 59

10,000 00
Appropriated by act approved March 3, 1873 ..... 10,000 00

The channel at this place is now 800 feet wide, being 400 feet wider than it was before the dredging was done.

Very respectfully,

H. A. BENTLEY,
Civil Engineer.

G. K. WARREN,
Major of Engineers, Bvt. Maj. Gen., U. S. A.

X 9.

WICKFORD HARBOR, RHODE ISLAND.

The amount appropriated for this work by act of Congress approved March 3, 1873, $5,000, was expended in dredging by contract at 40 cents per yard, and in removing one bowlder lying in the channel used by the steamer plying between Wickford and Newport.

There was little competition for this work, and in cases like it, where the amount of money is small, better bargains can be made than by advertising for proposals.

A survey of that part of the channel where dredging was done was made after the close of the work. The soundings taken at that time are shown in red in the accompanying sketch; the map and soundings in black are from the survey of 1872.

Amount of material removed, 11,213 cubic yards, at 40 cents $4,485 20
Cost of removing bowlder 100 00
Superintendence 414 80

5,000 00

The recent appropriation of $5,000 will be spent in the removal of obstructing points and in widening the existing channel.

No further appropriation for dredging will be at present required here. The great remaining obstacle in this harbor is James's Ledge, a large rock covered by but 2.7 feet at low-water, and marked only by a black spar-buoy. With my report on the survey of this harbor, dated December 24, 1872, incorporated in the annual report for 1873, was transmitted a contour map of this rock, with an estimate of $15,600 for its removal to 10 feet below mean low-water, to which report I now refer. A beacon sufficient to clearly mark this obstacle could be built at a cost of probably much less than the estimate for its removal; and as the channel at James's Ledge is of ample width, such an improvement would

meet the wants of navigation as well as, if not better than, this partial removal.

Wickford is in the Newport collection-district. Newport is the nearest port of entry. The amount of revenue collected during the fiscal year ending June 30, 1874, was $2,514.94.

Financial statement.

Balance in Treasury of United States July 1, 1873	$5,000
Amount appropriated by act approved June 23, 1874	5,000
Amount expended during the fiscal year ending June 30, 1874	5,000
Amount available July 1, 1874	5,000

X 10.

BLOCK ISLAND, RHODE ISLAND.

The appropriation of March 3, 1873, being early available, the contractor for extending the breakwater was enabled to get at work in June of that year. This work was actively prosecuted until October, at which time all was done in this way that was then desirable.

In these five months 13,657 tons of stone was deposited, at a cost of $2.93 per ton. During October and November we removed 446 tons of large bowlders from the inclosed area, at a cost of $4.75 per ton, and these were deposited in the breakwater. In extending the breakwater this year we reduced its section, so as to gain shelter more rapidly, diminishing the width on top from 30 feet to 15 feet, and the seaward slope from 1 on 3 to 1 on 2. The winter-storms show that this is an insufficient width, as we expected they would; but the amount of change effected was but little, and occasions no loss, as we can complete the work now at as little cost as if it had been all done at one time, besides having the benefit of a larger harbor at once. During the latter part of the past fiscal year we began to add to the facilities of the inner harbor by piling and making landings, as the greatly increased business of the place required. We could not allow private parties to build in this basin. The Fall River Iron Company, by due permission of the War Department, was allowed to build a wharf along the inside of the main breakwater, which is a valuable addition to the public facilities for business.

There is enough money on hand to entirely remove the bowlders where the water has a depth as great as 5 and 6 feet within the protected anchorage. The last appropriation of $20,000 it is proposed to use in strengthening the part of the breakwater built last year and in extending it about 100 feet further. This will be as far as it is desirable for it to go. It will then have been built 1,350 feet from the shore and out to a depth of 15 feet at mean low-water.

The next improvement required will be a detached piece, leaving an opening about 200 feet wide at the terminus of the main work, and extending northwesterly at an angle of about 45° with it and 300 feet long. This will complete the shelter from northeast storms. It is very desirable to have the amount sufficient for this appropriated all at once, for in an incomplete state it would prove a dangerous obstruction.

The further improvement consists in extending the jetty from the west shore to gain still-water behind it, and, if a greater draught is required, to gain this by dredging the sheltered area. No serious filling up has taken place in this part. The report of my assistant engineer,

Mr. J. P. Cotton, with map and all other details for investigating the conduct of this work, accompanies my report.

The appropriation of $60,000 for the next year is recommended.

Besides the protection afforded to common interests in storms, Block Island, under the beneficial influence of this public work, is becoming a place of much resort, and from the protection given to fishing-smacks, a large field is opened for the fishermen supplying the markets of our principal cities.

Block Island is in the Newport collection-district, and Newport is the nearest port of entry. The amount of revenue collected there in the fiscal year ending June 30, 1874, was $2,514.94.

Financial statement.

Balance in Treasury of United States July 1, 1873	$60,000 00
Amount in hands of officer, and subject to his check, (including $857.32 percentage due on contracts not yet completed)	6,551 55
Amount appropriated by act approved June 23. 1874	20,000 00
Amount expended during the fiscal year ending June 30, 1874	50,572 30
Amount available July 1, 1874	35,979 25
Amount required for the fiscal year ending July 30, 1876	60,000 00

Report of Mr. J. P. Cotton, Assistant Engineer.

ENGINEER OFFICE UNITED STATES ARMY,
Newport, R. I., June 30, 1874.

GENERAL: I have the honor to submit the following report of operations on the improvement of Block Island Harbor, Rhode Island, during the fiscal year.

At the date of my last report, August 31, 1873, the contractor for furnishing granite for the breakwater, under appropriation made by act approved March 3, 1873, Mr. Francis H. Smith, of New York, had already placed upward of 8,000 tons of granite in the work. He continued to prosecute the work diligently until the completion of his contract, October 31, 1873. The amount of granite put in the work by him is as follows: June, 1,463 tons; July, 2,852.7 tons; August, 4,200.3 tons; September, 3,644 tons; October, 1,497 tons; total, 13,657 tons.

This amount greatly exceeds that put in by any previous contractor on this work in the same length of time. His being able to deliver the stone so rapidly was mainly due to employing a steamer to carry stone and tow the sailing-vessels when there was no wind, and to the circumstance that the work is so far extended that vessels can unload in any weather when they can run to the island. The employment of a steamer was made a condition in advertising for proposals and awarding the contract.

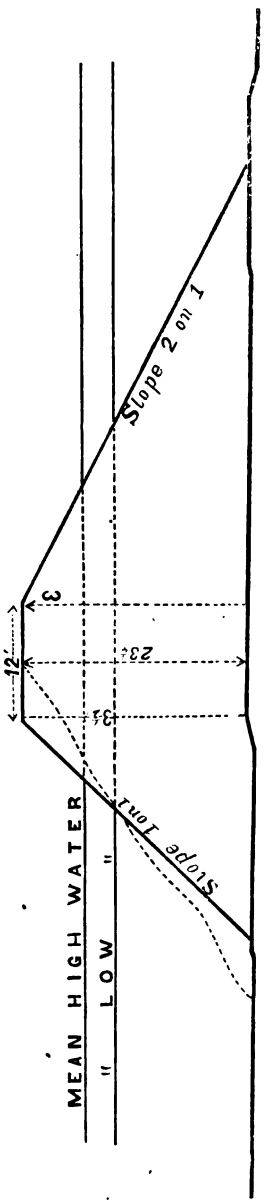
During October and November, 1873, about 446 tons of bowlders were removed from the anchorage sheltered by the breakwater, at a cost of $6 per ton. They were placed in the main work. An agreement has been made with parties to commence the removal of bowlders July 1, at $4.75 per ton. If from this we take the last contract-price of stone placed in the main work, we have for net cost of removal of bowlders $4.75−$2.93=$1.82 per ton. This price I regard as very favorable for the Government, and, in view of the increased value of the harbor, if entirely cleared of rocks, I would recommend that the work be continued until all are removed. If those using the harbor know that there is no danger from rocks on the bottom, they will anchor in much less water than they would if there was an occasional bowlder that they might strike. If they are removed, much of the harbor, with 6 to 8 feet depth at mean low-water, that is now useless because of them, will become available for small vessels, leaving the greater depth of water for those of greater draught.

Piles have been driven and the necessary lumber is on hand to complete the wharf on the east, south, and west sides of the inner harbor. These wharves will be completed during the season.

The Fall River Iron Company, of Fall River, Mass., obtained a charter from the legislature of the State of Rhode Island and permission of the honorable Secretary of War, to erect a wharf on the west side of the main breakwater outside of the inner harbor. They have built a pile-wharf 175 feet long and 20 feet wide, and intend to run a steamer to the island two days each week during the summer.

This wharf, built east of the opening of the inner harbor and close to the main breakwater, will serve the double purpose of a fender to prevent vessels from going on

to the rocks of the breakwater in case of misstaying in entering or leaving the inner harbor, and to warp to, before making sail, when the wind is from the north.



In May, 1874, soundings were made in the inner harbor and over the area sheltered by the breakwater, to see if the effect of the breakwater had been to fill up the harbor. These soundings, compared with those made soon after the work was commenced, do not indicate that filling has taken place to any extent, except over a very small area near the shore, where the water was so shoal as to be of little use, and this area is in the angle formed by the shore and the west crib of the inner harbor.

The dimensions of that part of the work built last season were less than that built heretofore, being but 10 to 15 feet wide, 6 feet above high-water, with a slope of 2 on 1 on the seaward side, and 1 on 1 on the shore side. With these dimensions the work stood the storms of winter very well, being but slightly modified in a few places by them. The changes made in dimensions in 1873 were in the width and in the seaward slope, the shore slope remaining the same, yet *this only* was changed by the waves.

An examination of the portion built with the original dimensions of 30 feet wide, with seaward slope of 3 on 1, and inner slope of 1 on 1, failed to discover any changes in the inner slope. From this it would appear that the fault in this part was not of slope, which alone showed the effects of the sea, but of width. The seas advancing upon it strike and run up the fore slope and break on top of the work. The weight of the sea with its motion proves too much for the work with its present cross-section. The annexed cross-section shows the effect of the sea, the full lines representing the work as constructed, and the broken lines a characteristic section in a part where the waves have modified it. Had this work been capped by a parapet with a vertical face toward the sea of sufficient strength to have withstood the waves, the *outer slope* would have received the shock of the receding wave. It was not anticipated that this cross-section would be sufficient to withstand the waves, but by building it thus we were able to get more shelter with the money spent than we could have had if it had been completed to its full width.

That part of the work built last season cost about $120 per foot of length. To complete it to the required width and cross-section will probably make the cost per foot $175. The extension of this work with its full width will probably cost $200 per foot.

With the remainder of the appropriation made by act approved March 3, 1873, it is designed to finish the wharves and remove the bowlders from the anchorage. The appropriation of $20,000, made by act approved June 23, 1874, will be expended in increasing the width of that part of the breakwater built last year and extending it as far as the funds will pay for. It is thought that the main work will then be extended as far as is necessary for a harbor for the class of vessels for which it was designed. It will then be necessary to turn the work to the westward, or to build a detached pier to protect the harbor from northeast storms, the only ones to which the anchorage is now exposed.

I think a detached pier 300 feet long, extending in a northwest and southeast direction, will best meet the requirements in the case, in that, while it keeps out the sea, it can be so placed as to offer but little obstruction in entering or leaving the harbor.

This pier should be placed at least 200 feet north of the head of the main work, in order to give an opening for vessels to leave the harbor in north and west winds and to enter in southerly and easterly winds.

When this detached pier is completed and the jetty on the reef extended to within

about 800 feet of it, the harbor will be completely sheltered in all storms, having an area of 17 acres, with from 5 to 15 feet of water at mean low-water.

This depth can be sufficiently increased by dredging to accommodate vessels likely to seek it for shelter for much less than the work could be extended to include deep water.

The probable cost of completing the harbor in accordance with the above plan will be:

For pier, 300 feet long, at $200	$60,000
For extending jetty 700 feet, at $25 per foot	17,500
Superintendence	8,500
	86,000

I have been assisted in this work during the season of active operations by Mr. G. N. Weaver, civil engineer.

Respectfully submitted.

J. P. COTTON,
Civil Engineer.

G. K. WARREN,
Major of Engineers, Bvt. Maj. Gen., U. S. A.

X II.

PAWCATUCK RIVER, RHODE ISLAND AND CONNECTICUT.

The $10,000 appropriated March 3, 1873, was all expended under the contract reported in my last annual report, work ceasing in November. The channel, 5 to 5½ feet deep, was carried up to the wharves at Westerly with a width of 40 feet, except at a bend, where it was made 60 feet wide.

The first survey, made in 1870, was hurriedly done and by inexperienced engineers, and was not as complete as desired. A new and careful survey was made in the season of 1873 by Mr. H. A. Bentley, assistant engineer, who had charge of the improvement. The map and his report are transmitted herewith. The report gives a full history of all the previous work and an estimate, based on the new survey, of what will be the cost of the additional improvements required to make the channel everywhere not less than 5½ feet deep at mean low-water and 75 feet wide. The mean rise of the tide here is only about 2½ feet. The amount of work remaining to be done at the close of the last season's operations will cost about $21,000. The amount appropriated June 23, 1874, $10,000, leaves $11,000 still to be provided, which it is recommended should be given all at once.

With the appropriation now on hand it is proposed to continue the dredging by widening the channel where it is most needed. Already the improvement of this river has greatly diminished the cost of freighting to Westerly.

The Pawcatuck River is the boundary between the Stonington and Providence collection-districts. Stonington is the nearest port of entry. The amount of revenue collected during the fiscal year ending June 30, 1874, at Stonington, was $30,346.14, and at Providence $184,197.37.

Financial statement.

Balance in Treasury of United States July 1, 1873	$10,000 00
Amount in hands of officer and subject to his check, (including $800.17, percentage due on contracts not yet completed)	1,858 42
Amount appropriated by act approved June 23, 1874	10,000 00
Amount expended during the fiscal year ending June 30, 1874	11,668 72
Amount available July 1, 1874	10,189 70
Amount required for the fiscal year ending June 30, 1876	11,000 00

Report of Mr. H. A. Bentley, Assistant Engineer.

ENGINEER OFFICE, UNITED STATES ARMY.
Newport, R. I., June 10, 1874.

GENERAL: I have the honor to submit herewith a report on the improvement of the Pawcatuck River, Rhode Island and Connecticut, embracing a history of the work since its commencement, a description of the survey made in 1873, and estimates for improvements still needed.

HISTORY OF IMPROVEMENTS COMPLETED.

A survey of this river, with a view to its improvement, was made in accordance with the second section of a bill making appropriations for rivers and harbors for the fiscal year ending June 30, 1871, which provided (among others) for a survey of the Pawcatuck River, Rhode Island and Connecticut.

This survey was made, under your direction, by Mr. John H. Dager, civil engineer, in the fall of 1870. It extended from Westerly to Little Narragansett Bay.

The map of this survey showed that a draught of 5 feet, at mean low-water, could be carried no farther up the river than Gravelly Beach; above this the water varied in depth from 2 to 4 feet.

Mr. Dager, in his report on this survey, deemed a channel 75 feet wide and 5 feet deep adequate to the commercial wants of Westerly.

Congress by act approved March 3, 1871, appropriated $10,000 for the improvement of this river.

Dredging having been decided on as the best way of opening the desired channel, advertisements were issued for proposals to do the work. It was awarded to Mr. E. R. Seward, of Albany, N. Y., the lowest bidder. Mr. Seward, however, did not commence work at the time specified in his contract, and, after waiting a reasonable time for him to commence, arrangements were made with Mr. M. F. Brainard, of Albany, N. Y., and Mr. T. J. Hill, of Providence, R. I., to do the work at about the same price as Mr. Seward had agreed to, (35 cents per cubic yard.)

Mr. Brainard's dredge commenced work in the latter part of October, 1871, at Certain Draw Point, and dredged one cut (throwing the material on the side) down to opposite Gravelly Beach, where it joined deep water. The channel here runs close to the shore, west of the cut made; owing to an insufficient number of soundings having been taken when the survey was made, this part of the channel was not shown on the map, and the cut was made before it was discovered. While the channel here needed straightening, it was not considered of so much importance as the deepening of the shoals above, because vessels could, with a litile trouble, navigate the old channel, whereas above it was impossible. The plan of operations was consequently changed. Mr. Brainard's dredge was set at work making a cut opposite Major's Island, throwing the material over the side, the depth of water here not being sufficient to float scows.

Mr. Hill's dredge arrived shortly after Mr. Brainard's, and was started at work a short distance above Pawcatuck Rock. The work up to this time was under the superintendence of Mr. H. A. Frink, civil engineer, who was relieved by Mr. H. S. Van Ingen, civil engineer. Mr. Van Ingen remained in charge until April, 1873, when, by your direction, I assumed charge of the work.

It was found necessary to change the depth to be dredged to from 5 to 5½ feet at mean low-water, in order to float the scows at low-water.

This appropriation completed a channel 40 feet wide and 5½ deep, to a point opposite the cemetery, except immediately above Pawcatuck Rock, where the channel was made 70 feet wide. It also completed a cut about 1,400 feet long opposite Major's Island.

By act of Congress approved June 10, 1872, $10,000 was appropriated for the continuance of this work. This money was expended in connecting the channel dredged up to the cemetery with the cut opposite Major's Island, and in widening this cut by making another along its side. The first cut made opposite Major's Island had filled in at several places to such an extent that it had to be redredged in order to make water enough to float the scows while making the second cut. The material from the first cut was thrown on the west side of the cut because the water was too shoal to use scows. The bank thus thrown up has washed down considerably, and it was undoubtedly part of the material of this bank that formed the shoals (in the first cut) redredged. This is, however, probably as economical a way as any other of opening a channel through so shoal a place.

By act of Congress approved March 3, 1873, $10,000 was appropriated for continuing this work. The money was expended in carrying the channel dredged, with the last appropriation, up to the Westerly wharves. This channel is 40 feet wide, except at the turn near the new ice-house, where it was made 60 feet.

The dredging under the appropriations of 1872 and 1873 was done by Mr. E. M. Payn, of Albany, N. Y., at the rate of 36¼ cents per cubic yard, and was completed in November, so that its benefit was partly realized that season.

CHARACTER OF MATERIAL DREDGED.

The material found in dredging that part of the river below Pawcatuck Rock was soft mud. Between Pawcatuck Rock and the cemetery it was sand and mud. Between the cemetery and Major's Island, fine river sand. In dredging this sand there would be occasionally brought up a layer of very fine white sand; it was generally between two layers of decayed vegetable matter. These layers were about 3 inches thick. Above Major's Island the material is gravel, so closely packed as to make it hard dredging for an Osgood machine.

SURVEY OF 1873.

The map of this river, made in 1870, was from a preliminary survey, and was not enough in detail to answer the purposes of a working drawing; besides this, it did not show the increased depth made by dredging. It was in consideration of these reasons deemed by you necessary to have a new survey made.

In accordance with instructions received, I, while prosecuting the improvement in September and October, 1873, made a complete new survey of the river from the dam at Westerly to about a half mile below Lottery.

The following is a description of the method of making this survey:

The river was covered by a system of triangles in which each angle was measured, the points on shore being fixed by stakes. These stakes were connected with the traverse lines by making them stations of these lines. The traverse lines were run on each bank of the river, the general topography along each line being taken.

Soundings, located by two angles from a known base, were taken over the part of the river surveyed. These soundings are referred to the mean low-water plane established by Mr. Van Ingen in April and May, 1872.

The observations by which this plane was established were made for a lunation, at the cemetery.

The mean rise and fall of tide is 2.3 feet. Mean low-water is referred to a bench-mark. This bench-mark is the bottom of upper drill-hole, in north side of granite post; in the end of fence forming north boundary of cemetery. It is 4.89 feet above mean low-water.

The map of this survey is platted to a scale of 200 feet to the inch, and is submitted herewith. This map shows a channel 5½ feet deep, and from 40 to 60 feet wide up to Westerly, with two exceptions, one opposite the cemetery and one opposite the new ice-house; at these places there is a depth of about 5 feet at mean low-water.

IMPROVEMENTS NEEDED.

The channel as now dredged is only about 40 feet wide. To complete the improvements contemplated (a channel 75 feet wide) will require the removal of 45,000 cubic yards of material, which at 36½ cents would cost $16,425. In addition to this, about $2,000 is needed to straighten the channel at Certain Draw Point, and about $500 for the removal of rocks along the channel.

RECAPITULATION OF ESTIMATES.

To widen the channel to 75 feet, 5½ feet deep at mean low-water	$16,425 00
To straighten channel at Certain Draw Point	2,000 00
For removal of rocks	500 00
Ten per cent. for engineering and contingencies	1,892 50
Amount required to complete improvement	20,817 50

The estimates heretofore made for this river have all been too small, because they were made from the old map, which did not show the channel accurately, and because the greater part of the material to be dredged is fine sand, which runs into a dredged cut from the sides to such an extent as to require the digging to be carried to a greater depth, in order to leave the required depth. A channel of the width and depth recommended will be ample for all vessels that can enter this river, the bar at the mouth precluding vessels drawing more than 5 feet at low-water or 7 feet at high-water from entering the river.

The mouth of this river is in Little Narragansett Bay. As we have no map showing the present condition of this bay, no reliable estimate can be formed of the obstruction here. A map of this locality, made by the United States Coast Survey in 1839 and in 1855, shows that Napatree Point, which separates the bay from the ocean, is gradually extending out into the channel of the bay. A survey of this bay is very much needed to show whether Napatree Point is still growing, and what the depth of water is in the channel.

If this survey should be made it would also enable us to better understand the action of the tides of this river.

The total number of cubic yards removed by dredging from the river since the commencement of the work, including that thrown over the side, is 70,575.

The improvement already made in this river has been the cause of a reduction in the freights to Westerly, amounting to 75 cents per ton.

The work of dredging has been under the immediate inspection of Capt. S. Gavitt, of Westerly.

I was assisted on the survey of the river by Messrs. W. C. Graham and W. F. Hill, civil engineers.

Respectfully submitted.

H. A. BENTLEY,
Civil Engineer.

G. K. WARREN,
Major of Engineers, Bvt. Maj. Gen., U. S. A.

X 12.

STONINGTON HARBOR, CONNECTICUT.

The work of dredging under the appropriation of $25,000 by act approved March 3, 1873, was commenced October 2, 1873.

That part of the harbor between the breakwater and old steamboat-dock, and between the channel and wharves, has been dredged to a depth of 12 feet at mean low-water; except a small space in the upper part of the harbor, where a wharf is projected, and a space immediately next the wharves. The dredging of these places would have been of benefit to the property-owners only.

The work completed affords a small anchorage that is completely sheltered, but this area is inadequate to the accommodation of the number of vessels seeking shelter there during storms. It is proposed to expend the appropriation of $20,000 by act approved June 23, 1874, and what remains of the previous appropriation, in dredging off the upper end of Penguin Shoal. This will give a direct increase of the anchorage-ground of about 45 acres, and afford an easy access to the deeper portions of the harbor inside the steamboat-wharf. It has been one of the plans contemplated to deepen this inner space, and it may be desirable to do so, as the digging is easy.

It must be stated that the plan first recommended was to construct two new breakwaters, exterior to the existing one running out from Stonington Point and Wamphassuck Point toward each other, at a cost of $420,000. The small appropriation made, and the requirement of the law that it must be expended in dredging, compelled us to abandon that plan and resort to what we have done and what we propose to do the fiscal year beginning July 1, 1874. Dredging alone, however, will not give the shelter required, and an additional breakwater is necessary to enable vessels to hold by their anchors in southerly gales.

The plan now recommended does not contemplate any change in the existing breakwater, but the building of another on the outer part of Penguin Shoal, beginning nearly west of the end of the present breakwater, where the depth is 12 feet at mean low-water, leaving an entrance between them about 450 feet long, and extending it westerly over the highest part of Penguin Shoal till it reaches the 9-foot curve on the west side of this shoal. This will make it about 1,200 feet long. It is to be built of heavy riprap granite, no stone less than a ton in weight, with seaward slope 1 on 2, width on top 6 feet, inside slope 1 on 1, and rise 7 feet above mean low-water. The mean rise of the tide here is 2½ feet. This will require—

Thirty-five thousand tons of stone, at a cost of, say, $2.50 per ton, making $87,500, to which add $3,500 for engineering and superintendence, requiring for the whole work $96,090.

If any further work is done here, I recommend the building of this breakwater as most important. The accompanying map shows the condition of the harbor where the dredging has already been done and the location of the breakwater on Penguin Shoal. Accompanying also is the report of Mr. H. A. Bentley, assistant engineer, who superintended the work and made the accompanying map.

Stonington is in the Stonington collection-district, and is a port of entry. The amount of revenue collected during the fiscal year ending June 30, 1874, was $30,346.14.

Financial statement.

Balance in Treasury of United States July 1, 1873	$25,000 00
Amount appropriated by act approved June 23, 1874	20,000 00
Amount expended during the fiscal year ending June 30, 1874	21,047 22
Amount available July 1, 1874	23,952 78
Amount required for the fiscal year ending June 30, 1876	96,000 00

Report of Mr. H. A. Bentley, Assistant Engineer.

ENGINEER OFFICE, UNITED STATES ARMY,
Newport, R. I., June 30, 1874.

GENERAL: I have the honor to submit the following report of operations in Stonington Harbor, Connecticut, during the past fiscal year:

By act of Congress approved March 3, 1873, $25,000 was appropriated for the improvement of this harbor. The act appropriating this money specified that it should be spent in dredging.

It was decided by you to have the harbor between the breakwater and the old steamboat-dock dredged to a depth of 12 feet at mean low-water, to increase the anchorage facilities of that part of the harbor sheltered by the breakwater.

The work of dredging was contracted for by Mr. S. F. Shelbourne, of New York City, at the rate of 20 cents per cubic yard.

The dredge arrived at Stonington October 1, 1873, and was set at work October 2, commencing at the 12-foot contour line and working in toward the docks, the cuts running north and south. These cuts were at first carried up to the deep water alongside the old steamboat-dock, but afterward, learning that the steamboat company intended building a new dock out from the east shore to the snubbing-pier, the dredging was stopped before reaching the proposed line of wharf. The building of this wharf would render that part of the harbor between the snubbing-pier and the old steamboat-dock of no value as anchorage-ground.

The dredging was prosecuted during October, November, and December, 1873, and February, May, and in June, 1874, up to date; this being the time specified in the contract for completing the work.

The material in the upper part of the harbor is closely-packed sand, while in the lower part of the harbor it is soft mud.

The dredging done has deepened the harbor between the breakwater and the snubbing-pier, from the channel on the west to within 30 feet of the heads of the wharves, from a depth of from 7 to 11 feet, to 12 feet at mean low-water.

Before this dredging was done, most vessels putting into this harbor during storms anchored outside the breakwater, the shoal water inside compelling them to lie so close to the steamboat-channel that they were in constant danger of being run down by the steamers of the Stonington line. Since the improvement here a great many vessels have availed themselves of the sheltered space.

The total number of cubic yards removed under Mr. Shelbourne's contract is 91,087.

The work done gives 12 feet depth over the whole area between the steamboat-channel, the breakwater, and the steamboat-dock. The remainder of the appropriation can be expended to most advantage with the new appropriation in dredging Penguin Shoal.

By act of Congress approved June 23, 1874, an additional appropriation of $20,000 was made for this work.

I would respectfully recommend that this money be expended in dredging off the upper end of Penguin Shoal to a depth of 12 feet at mean low-water. It is estimated that the available money will be sufficient to remove this shoal nearly as far south as a line of prolongation of the outer portion of the breakwater.

The improvements made and that recommended in this report include, I think, all the dredging needed in this harbor, which, with a suitable protection from southerly storms, would make an excellent harbor of refuge.

Very respectfully, your obedient servant,

H. A. BENTLEY,
Civil Engineer.

G. K. WARREN,
Major of Engineers, Bvt. Maj. Gen., U. S. A.

X 13.

CONNECTICUT RIVER BELOW HARTFORD, AND SAYBROOK BAR, CONNECTICUT.

At the date of my last annual report, August 31, 1873, a dredge had been employed in deepening the water on Pratt's Ferry, Hartford, and South Glastonbury Bars. This dredge was employed during July, August, and a part of September, removing the following quantities from each place, making a depth of 9½ feet, and a width of 50 to 70 feet:

	Cubic yards.
Hartford Bar	9,088
Pratt's Ferry Bar	7,081
South Glastonbury Bar	1,400
Total	17,569

At a cost of $4,350, or about 24.8 cents per cubic yard. The dredging on these bars was for the most part in the channel dredged through them in 1871, where a depth of 9½ feet was made; it had filled up to less than 8 feet at ordinary low-water, making passage for the daily steamers running between New York and Hartford difficult and uncertain.

It is probable that these channels will be filled up by every flood and require dredging at the season of low-water. The exact location and extent of the work cannot, however, be determined with sufficient definiteness to warrant the making of specifications in time to issue them with those for other works. I propose, therefore, to hire a dredge by the day when the water becomes so low as to make the bars troublesome to navigation.

The construction of the jetty at Saybrook Bar was in progress at the date of my last annual report. Work was continued on it until the funds available for the work were expended. The jetty is now 1,600 feet in length, 17,504 tons of stone being used in the construction. It is built up to the level of highest water, triangular in cross-section, with side-slopes of about 45°. A wooden beacon marks the outer end.

An examination of the jetty this spring showed that it had been but little affected by the ice and waves during the winter.

This jetty is not expected to produce the desired effect in deepening the water until it is extended to the deep water beyond the bar, about 100 feet beyond its present terminus.

About $5,000 will be required for the dredging that may be necessary; the remainder will be used in extending this jetty.

We should have $70,000 additional to finish the jetty at the mouth, and about $10,000 for dredging.

The Connecticut River below Hartford is in the Middletown collection-district. Middletown is the nearest port of entry. The amount of revenue collected there during the fiscal year ending June 30, was ——.

Financial statement.

Balance in Treasury of United States July 1, 1873	$45,000 00
Amount in hands of officer and subject to his check, (including $281.20, percentage due on contracts not yet completed)	1,730 43
Amount appropriated by act approved June 23, 1874	20,000 00
Amount expended during the fiscal year ending June 30, 1874	42,713 37
Amount available July 1, 1874	24,017 06
Amount required for the fiscal year ending June 30, 1876	80,000 00

X 14.

CONNECTICUT RIVER ABOVE HARTFORD, CONNECTICUT, AND BELOW HOLYOKE, MASSACHUSETTS.

During the past fiscal year work in this portion was mainly confined to completing a thorough survey of it. This has now been done, and the maps finished on a scale of 400 feet to the inch, forming six sheets. The maps and a diagram of borings made, with a preliminary report of Assistant Engineer Gen. Theo. G. Ellis, who conducted the survey, are presented herewith. Some few other observations in connection with gauging the low-water volume of the river remain to be done, and then the final report, giving a review of the whole matter, will be made.

The last annual report gave a clear general idea of what had been done up to that date, and it need not be repeated here.

During the season of 1873 a channel 2½ feet deep was dredged through Barber's Landing Bar. This was the only improvement then needed.

The surveys last year showed that the wing-dams between Hartford and the Enfield Falls, as far as built, had been very beneficial, and that this means of improvement would probably be adequate to present requirements of navigation, or until there is a great improvement made at the Enfield Falls. An expenditure of not less than $87,000 will be required for the improvement of these falls alone. (See Annual Report for 1872.) Until the improvement of the river is undertaken with a view to carrying it to the extent which this contemplates, and until the ruling depth to be secured is fixed, the kind of improvement to be adopted at different localities cannot be decided. With the present small appropriations only alleviations of obstructions to existing navigation can be attempted, and the requirements of this are determined by the existing canal and locks.

Our survey shows no place between the Enfield Falls and Holyoke where the present class of vessels find any obstruction or need any greater facilities than they now have.

Of the appropriation of $25,000, appropriated June 10, 1872, for improvement "on or above Enfield Falls and below Holyoke," we have expended about half in surveys and measurements. We find, as before said, no place where the remainder can be used above the falls, and it is inadequate to doing anything upon them.

Of the former appropriations for improvement above Hartford and below Holyoke there is on hand $21,772.31, which by the words of the act is available to improve the river between Hartford and Enfield Falls. It is proposed to expend the money in this portion of the river by building wing-dams and dredging, as the formation of shoals may require.

The improvement of the Connecticut below Hartford is more important to the whole Connecticut River Valley than is the improvement above, and for the present it would be better to confine the expenditures to the lower part of the river.

The appropriation of $25,000, made by act approved June 10, 1872, is applicable to the river only "on or above Enfield Falls and below Holyoke;" a part of the river where there is sufficient depth of water for the class of vessels navigating it. What remains on hand of this appropriation is not available for any part of the river where it is needed. In making up the "financial statements" this appropriation is given in a separate statement.

Financial statement.

Connecticut River from Enfield Falls to Holyoke, Mass.

Balance in Treasury of United States July 1, 1873	$25,000 00
Amount expended during the fiscal year ending June 30, 1874	12,391 45
Amount available July 1, 1874	12,608 55

Connecticut River above Hartford and below Holyoke, Mass.

Balance in Treasury of United States July 1, 1873	$25,000 00
Amount in hands of officer and subject to his check	1,606 65
Amount expended during the fiscal year ending June 30, 1874	4,834 34
Amount available July 1, 1874	21,772 31

Report of Gen. Theo. G. Ellis, Assistant Engineer.

HARTFORD, CONN., *July* 6, 1874.

GENERAL: In compliance with directions received, I transmit a preliminary report of the survey of the Connecticut River from Hartford to Holyoke.

The survey of the Connecticut River between Hartford and Holyoke was commenced in the latter part of August, 1872, by a small party under Mr. William F. Dyer, civil engineer, who started the field-work at Holyoke and continued down the river to near Chicopee Village. Work was suspended in the latter part of October of that year, and a plot was made of the work then completed.

The survey was resumed early in April, 1873, and two field-parties were employed upon the work.

One under Mr. Wm. F. Dyer, civil engineer, continued the field-work down to Enfield Dam; and another, under Mr. Charles L. Burdett, civil engineer, made the surveys from Enfield Dam to Hartford.

The surveys were continued during the season until suspended, about the 1st of October, when the field-work was mostly completed. In October and November borings were made in the bed of the river at several points between Hartford and Holyoke to determine the depth of the rock.

During the past winter the maps and drawings have been completed by Mr. Burdett, Mr. Dyer, Mr. Burnett, and Mr. Curtis.

During the present season observations have been taken by a field-party under Mr. Burdett to determine the discharge of the Connecticut and the streams entering into it between Hartford and Holyoke. These observations are not yet completed, owing to the continued high-water. The ganging of the Connecticut has been mainly done at a point just above Thompsonville. Accurate ganging cannot be done at low stages of the river below Enfield Rapids on account of the tides.

METHOD OF MAKING THE SURVEYS.

The method adopted in making this survey has been to run a base-line on each side of the river, and connect all the angles by a system of triangulation. The instruments used were Gurley transits reading to minutes. By repetition, the angles were determined to the nearest 10 seconds.

The shore-lines of the river and the details of the topography were connected by angles and measurements to the base-lines. All side surveys of roads, &c., were made by running transit-lines by angles and distances from the base-lines.

Soundings across the river were taken at intervals of 400 feet, and in the vicinity of bars and shoals at shorter intervals, generally 100 feet, and reduced to the lowest stage of water. These soundings were made from boats rowed directly across the river, keeping in range with poles set upon the banks, generally at right angles to one of the base-lines. The points where these ranges cut the base-lines were accurately fixed, and the boat was rowed as uniformly as possible from shore to shore. The distance of the first sounding from the shore was noted and the intermediate ones were equally spaced. They were taken at equal intervals, measured by a certain number of

strokes of the oars, which has been found to give better results than equal intervals of time.

Sections across the whole valley at distances of from 1,200 to 2,000 feet apart were carefully leveled over, all intersections with roads, streams, &c., being noted, and the intervening topography carefully sketched in, with angles to the more prominent objects.

Levels were taken to all the high and low water marks that could be found, and were considered reliable with the date of the freshet.

An attempt was also made to locate the crests of all the bars, by means of micrometer hairs in a transit telescope and a rod used as a telemeter. Whenever there was found a distinct and perceptible crest it has been located upon the maps; but in many cases there appeared to be no distinct continuous crest presenting the characteristic steep slope upon the lower side generally seen in river-bars, giving them rather the character of shoals than proper river-bars, which are formed from the material carried along the bottom by the current. It may be here remarked, that all the bars upon the river below Hartford, as well as those between Enfield Dam and Holyoke, are of the shoal form, and do not present the steep lower side above referred to.

The discharge of the smaller streams running into the Connecticut has been mainly obtained by computing the greatest and least quantities flowing over the dam nearest to the mouth of the stream, together with what is used by the factories. The greatest amounts were most easily obtained and are the most reliable, as there is generally a good record of the highest point to which the water has risen upon the dam. The least quantity is often indeterminate, as the water is frequently held back and stored in ponds above, so that during a portion of the time no water at all runs in the bed of the stream. The factories then get no water until those above on the same stream are started. In such cases an estimate has been made of the amount of water used by the water-wheels at the lowest stage during running hours, and this quantity taken for the discharge in twenty-four hours. When no other method presented, the best possible estimate was made from the character of the stream. The mean discharge has been mainly obtained from the drainage area of each stream, as nearly as can be ascertained from maps. Five-eighths of the average amount of rain-fall has been taken, as it has been found by comparing the approximate discharge of the Connecticut with the average annual amount of rain-fall that about that proportion passes off through the river.

DESCRIPTION OF THE RIVER.

The river between Hartford and Holyoke can be divided into three characteristic sections:

1st. From Holyoke to Enfield Dam, a distance of 18.4 miles, in which the surface at low-water has a very slight inclination and the water is generally deep and with a slow current.

2d. From Enfield Dam to the foot of Enfield Rapids, a distance of five and one-fourth miles, in which the water flows over a rocky bed of steep inclination.

3d. From the foot of Enfield Rapids to Hartford, a distance of 10.9 miles, in which the river runs over a sandy bottom through an alluvial formation with an inclination greater than that above Enfield dam, but still to a certain extent navigable.

At the upper end of the survey the river flows over Holyoke Dam, a substantial structure of timber built upon the bed-rock of the river, having an average height of about 30 feet.

The main body of the dam, which was built in 1849, consists of a cob-work of square timbers brought up in layers. The timbers lying lengthwise with the current slope back up-stream at an angle of 2½ horizontal to 1 vertical; they are laid alternately with intermediate layers of horizontal timbers across the stream, and the whole is filled in solid with stone.

In 1869, the rock in front of the dam having been excavated to a depth of 25 or 30 feet by the force of the overflow, a cob-work 50 feet wide, forming an apron, was added to the dam to strengthen it. It is composed of round timbers 6 feet apart, with the interstices filled with stone. The abutments and gates are of good workmanship, but are not sufficiently high, and are in danger from this cause, the water in 1862 having risen above the masonry. Below the dam the river forms a rapid for about two miles down to just below the railroad-bridge at Willimansett; the whole fall being about 58 feet.

Boats formerly ascended this rapid to the villages of Holyoke and South Hadley, through an artificial channel at the lower end, near the west bank, and passed through the South Hadley Falls Canal, which has now fallen into ruins, not having been used for many years.

The river, over the rapids, runs between high banks and spreads out very little over meadows at high-water until it reaches the mouth of Chicopee River. It then overflows the meadows at high-water, or when it rises to a little more than half the height of extreme freshets nearly the whole distance down to a point about two miles above

Thompsonville. There are contractions of the banks at Chicopee Bridge, Springfield and Pecowsic, but for no great distance.

From the point about two miles above Thompsonville to Enfield Dam, a distance of two and three-fourths miles, the river is confined between its banks at all stages of the water, and this part presents the most available place for gauging the volume of the stream.

Enfield Dam is a low structure at the head of the rapids, and is open in the middle for 155 feet, which was intended originally to allow vessels and fish to pass; but this space has been filled in with stone to such an extent as to prevent the passage of boats. From the foot of the rapids below Holyoke to Enfield Dam, there is good navigation, with over 7 feet of water in the channel, except at the flats near the mouth of Chicopee River and at Longmeadow Flats, about half way between Springfield and Thompsonville. At the former place there is but 4 feet, and at the latter a little less than three feet at extreme low-water.

These shoals do not appear to have the same formation as the bars in some of the more rapid portions of the stream, and do not present the sharp and well-defined crest which is produced in river-bars by the motion of the sand along the bottom. They seem to be simply flats formed by the widening of the bed of the river between the ordinary banks. This is particularly the case at Longmeadow, where the bed of the river at low-water is 2,000 feet wide and keeps nearly this width for about a mile.

The bed of the stream, from Holyoke Dam down as far as the foot of the rapids below Willimansett Bridge, is mostly rock. From that point to Springfield it is mainly sand and gravel. For two miles below Springfield it has a more muddy character, with a point of rock cropping out near Pecowsic. From two miles below Springfield to near Thompsonville the bottom is again sand and gravel, and from this last point to Enfield Dam the bottom is rock.

Across this portion of the river between Holyoke and Enfield dam are the following bridges:

A wood and iron truss-bridge at Holyoke, for highway, 1,600 feet long, consisting of ten spans of 160 feet each.

A wooden truss-bridge between Willimansett and Holyoke, upon the Connecticut River Railroad, 750 feet long, with five spans of 150 feet each.

A wooden truss-bridge at Chicopee, for highway, 1,190 feet long, having seven spans of 170 feet each.

An iron railroad-bridge at Springfield, 1,260 feet long, consisting of seven spans of 180 feet each.

A wooden truss-bridge for highway, at Springfield, 1,200 feet long, with six spans of 100 feet each, and three spans of 200 feet each.

These bridges are all built upon stone piers; they are but little above the highest water, and have no draws.

There is a wire-rope ferry at Willimansett, just below Holyoke, and steam-ferries just below Springfield, at Pecowsic, and at Thompsonville.

From Holyoke to Chicopee the average width of the river at low-water is about 800 feet.

From Chicopee to Springfield the average width is about 1,000 feet, and from Springfield to Enfield Dam the average width is about 1,400 feet, at low-water.

In high freshets the river remains within its banks down to the mouth of the Chicopee, but then spreads out over the meadows, overflowing its banks and backing up the channels of the Chicopee and Westfield Rivers, covering the low land in many places for over a mile in width.

There is at the present time no navigation around Holyoke Dam. Locks of 16 by 80 feet are provided in the canals of the Holyoke Company as far as they are completed, and as this company has assumed the franchise of the old South Hadley Falls Company they would probably extend the locks to the foot of the falls if required by navigation.

The Enfield Rapids extend from Enfield Dam down the river about five and a quarter miles, the stream dividing at one place, about midway of the rapids, into two branches around King's Island.

The bed is rough and rocky, and the river runs between high banks. Around these rapids is the canal of the Connecticut River Company, mostly used at the present time as a water-power; but it is provided with locks 19 feet in width and 90 feet between quoins, through which there is still some navigation, although the small size of the locks prevents the passage of such boats as are used for freighting on the lower portion of the river.

There are two bridges over these rapids, one at Enfield, about 950 feet long, extending over the river and canal, in six spans of irregular length. This is an old and dilapidated wooden structure. The other is the iron railway-bridge over the river and canal at Warehouse Point, consisting of one span of 177 feet, twelve spans of 88½ feet, one span of 140 feet, one span of 77 feet, one of 43 feet, and one of 25½ feet; in all, 1,524½ feet.

There is also a flying ferry between Windsor Locks and Warehouse Point. The average width of this part of the river is about 1,100 feet.

For a more particular description of this part of the river, I would respectfully refer to my special report upon the improvement of these rapids, dated January 10, 1872. (See Annual Report for 1872, p. 840.)

From the foot of Enfield Rapids to Hartford the river has a steeper slope than above the dam at Enfield, and has in consequence a somewhat different character. Although it receives a considerable accession of volume from the Scantic and Farmington Rivers, the channel is shoaler and the cross-section smaller than above the rapids, owing to the greater velocity of the current.

The bars also are generally of a different character from those above, presenting a a flat slope up stream, and a steep declivity down stream, with a well-defined crest, as usually seen in rivers with a sandy bottom and considerable current.

This part of the river, below Red Hill, nearly opposite the foot of the canal at Windsor Locks, flows wholly through an alluvial formation. The banks appear to be nearly permanent down as far as the mouth of the Scantic River, from which point downward they are washing and caving off to some extent. For about two miles above the railroad-bridge at Hartford they are washing very badly; in some places losing probably 30 or 40 feet in a year.

Between Hartford and the lower end of the canal of the Connecticut River Company at Enfield Rapids there is a navigable channel, with a minimum depth of about 4 feet of water, except upon the bars. There are five bars upon this portion of the river, viz:

Scantic Bar, at the mouth of the Scantic River, seven and a half miles above Hartford, with 2.4 feet of water at the lowest water as the bed of the river now is.

Strong's Island Bar, six and a half miles above Hartford, with 2.5 feet at the lowest water.

Farmington or Tunxis River Bar, five and a half miles above Hartford, with 2.4 feet at the lowest water.

Barber's Landing Bar, three and two-thirds miles above Hartford, with $\frac{8}{10}$ foot of water at the time of the survey in July, 1873. Dredging was done here immediately after, which increased the depth to 2¼ feet.

Higley's Point Bar, one and three-quarters miles above Hartford, upon which there are 2.7 feet at the lowest water.

The first three of the above-named bars were improved by the United States Government in the year 1871, by the construction of wing-dams, as shown on the maps. They were built of riprap, and are now in a good state of preservation. In the summer preceding the building of these wing-dams the depth on Scantic Bar was 1.2 feet; on Strong's Island Bar, 1.3 feet, and on Farmington River Bar, 1.5 feet. It will thus be seen that they have materially benefited the channel. At Barber's Landing Bar, in the same season, the depth was one foot, or about what we find it by the present survey. The bed of the river, from the foot of the rapids to Hartford, is sand and gravel. No rock appears at the surface, although in some places it must be quite near it, as shown by the borings. The width of the bed of this portion of the river averages about 1,400 feet. At Hartford the banks are much contracted, being only about 600 feet wide opposite the New York, New Haven and Hartford Railroad freight-house.

At the lowest stages of water, upon this section of the river, large sand-banks appear upon the sides of the stream within the bed, so that the width for a great part of the distance is reduced to about one-half of the width of the bed between the ordinary banks. In some places it is only 500 or 600 feet.

In times of the highest freshets the water overflows the meadows on either side, and spreads out in some places to a width of one and a half miles, and has an average width of about one mile. Near the mouth of the Hockanum River there is a very decided contraction of the high-water section, caused by the embankment running to the ferry on the west side of the river, the extreme width at this place being 1,900 feet.

Just below Hartford there is a shoal, called Hartford Bar, upon which there is a little over 6 feet at extreme low-water. This was improved in 1871 by building a wing-dam of piling, about 650 feet long, from the west bank, and by dredging in 1871 and 1873. The wing-dam appears to have but little influence upon the depth of water in the channel, and the effect of the dredging is but temporary; it benefits the channel for one or two seasons only. The wing-dam is, however, very important in protecting the bank from washing.

There are two bridges upon this part of the river, both at Hartford. One is the wooden truss-bridge of the Hartford, Providence and Fishkill Railroad, 1,200 feet long, with seven spans of 160 feet each, and a draw at the east end with a clear opening of 47 feet. The other is the Hartford toll-bridge, an old, dilapidated wooden truss, in which subsequent additions barely support the original structure. It is 960 feet long, having five spans of 165 feet each, one span of 100 feet, and a draw at the west end of 17 feet clear opening. This latter bridge has a causeway leading to it across the meadow upon the East Hartford side, with openings to increase the water-way. The railroad-bridge has a trestle-work on piling across the overflowed meadows.

About one and one-half miles below the central part of Hartford, at the lower end of the dike, is a steam ferry running to the lower part of East Hartford. There is also a swing ferry at the mouth of the Scantic River, between Windsor and East Windsor.

TIDES.

The lower part of the Connecticut River is affected by the tide from Long Island Sound. At Hartford the fluctuations are very irregular, being modified and sometimes entirely neutralized by the wind. They are generally perceptible when the water is below 5 feet at Hartford.

At the lowest water in summer the tides are more regular, and average about 10 inches in range. The effect of the tides at low-water is not generally noticeable at the mouth of the Scantic River, seven and one-half miles above Hartford, although very high tides at low-water, with a strong southerly wind, are perceptible up to the foot of the rapids at Windsor Locks.

THE SLOPE OF THE RIVER.

The height of Holyoke Dam, at the ends, is 97.60 feet above low-water mark at Hartford Toll-bridge. The dam is lower at intermediate points, so that at low stages all the water is discharged at, or perhaps below, this level over the central part of the dam. The low-water slope of the surface, in the following table, commences at the above height as the water flows over the dam.

Low-water slope from Holyoke Dam to Enfield Dam.

Distance in miles.	Fall in feet.	Fall per mile in feet.
Dam	29.00	Vertical.
.10	.60	6.000
.30	20.40	68.000
1.76	8.90	5.057
16.20	.70	.043
18.36	59.60	

The height of Enfield Dam is irregular, and has, as before stated, an opening in the middle. At the lowest water nearly or quite the whole volume passes through this opening at a level of about 38 feet above the Hartford zero. The average level of the dam is about one foot higher.

High-water slope from Enfield Dam to the foot of the rapids.

Distance in miles.	Fall in feet.	Fall per mile in feet.
Dam	2.80	Vertical.
.91	6.40	7.033
1.44	1.40	.972
1.48	17.80	12.027
1.42	3.40	2.394
5.25	31.80	

Low-water slope from the foot of Enfield Rapids to Hartford.

Distance in miles.	Fall in feet.	Fall per mile in feet.
3.54	1.70	.480
7.35	4.50	.612
10.89	6.20	

eight of low-water at Hartford is zero of the gauge at the toll-bridge, and is
› of all the levels upon this survey. The highest known water above Holyoke
as found to be 110.60 feet above the Hartford low-water mark, or 13 feet above
t of the dam at the ends.
igh-water slope of the river, as determined by levels to the best authenticated
ater marks, is as follows:

High-water slope from Holyoke Dam to Enfield Dam.

Distance in miles.	Fall in feet.	Fall per mile in feet.
.....	29.	Vertical.
.....	11.10	55.500
.....	3.30	2.129
.....	3.90	.869
.....	—.50	—.242
.....	.50	.909
.....	3.60	1.837
.....	5.50	.802
.....	3.80	5.588
.....	60.20	.....

Low-water slope from Enfield Dam to the foot of the rapids.

Distance in miles.	Fall in feet.	Fall per mile in feet.
.....	8.90	5.
.....	8.70	4.462
.....	.....	.....
.....	17.60	.....

High-water slope from the foot of Enfield Rapids to Hartford.

Distance in miles.	Fall in feet.	Fall per mile in feet.
.....	.60	.169
.....	2.40	.327
.....	3.00	.....

igh-water mark at Hartford is the height of the flood of 1854, the highest known,
s taken as 29.80 feet above the zero of the gauge. There are two places upon
er where the high-water marks appear to give a reverse slope to the surface.
between Chicopee and Springfield, where the upward slope amounts to .5 of a
about two miles, and the other is at the foot of Enfield Rapids, where the sur-
s called level in the previous survey of Enfield Rapids, and is so retained in the
ng tables.
cause of this apparent anomaly is not determined, the high-water marks being
uthenticated. It is proposed to find others, if possible, to verify or show the
f those already obtained.

STREAMS FLOWING INTO THE CONNECTICUT.

first stream of any size flowing into the Connecticut below Holyoke is the Chico-
er, which enters on the east side just above the village of Chicopee. It is used
ater-power for the manufacturing establishments in the village. Its greatest
ge is 9,635 cubic feet per second; its mean discharge is 1,374 cubic feet per
; its least discharge is 669 cubic feet per second.

The west stream is the Agawam or Westfield River, which enters upon the west side opposite Springfield. This has many factories upon it in the villages through which it passes. Its greatest discharge is 28,633 cubic feet per second; its mean discharge is 1,287 cubic feet per second; its least discharge is 500 cubic feet per second.

Mill River, entering from the east, through the lower part of Springfield, is a stream of some importance, and is used as a water-power by the United States armory and other manufactories. Its greatest discharge is 899 cubic feet per second; its mean discharge is 63 cubic feet per second; its least discharge is 30 cubic feet per second.

The Pecowsic Brook, entering the river about one mile below Springfield, on the east side, is also used as a water-power for manufacturing purposes. Its greatest discharge is 151 cubic feet per second; its mean discharge is 15 cubic feet per second; its least discharge is 12 cubic feet per second.

Freshwater Brook, entering the river on the east side, through Thompsonville, is used as a water-power by the Hartford Carpet Company. Its greatest discharge is 1,598 cubic feet per second; its mean discharge is 18 cubic feet per second; its least discharge is 9 cubic feet per second.

A small brook entering the river on the west side, opposite Thompsonville, is also used as a water-power. Its greatest discharge is 200 cubic feet per second; its mean discharge is 2 cubic feet per second; its least discharge is 1 cubic foot per second.

Stony Brook enters the river on the west side, opposite King's Island, about two miles above Windsor Locks. It is used for a water-power. Its greatest discharge is 1,000 cubic feet per second; its mean discharge is 43 cubic feet per second; its least discharge is 20 cubic feet per second.

Scantic River is the next stream of any size. It enters the river seven and one-half miles above Hartford, on the east side, and has a number of mills upon it. Its greatest discharge is 6,116 cubic feet per second; its mean discharge is 139 cubic feet per second; its least discharge is 35 cubic feet per second.

The Farmington or Tunxis River is a large stream entering the river upon the west side, five and one-half miles above Hartford, It is used extensively as a water-power in the several villages through which it runs, and is quite an important stream. Its greatest discharge is 24,375 cubic feet per second; its mean discharge is 944 cubic feet per second; its least discharge is 450 cubic feet per second.

Stoughton's Brook, opposite the mouth of the Farmington, is a small stream, used as a water-power. Its greatest discharge is 143 cubic feet per second; its mean discharge is 5 cubic feet per second; its least discharge is 3 cubic feet per second.

The Podunk River enters on the east side, about two miles above Hartford. It is used as a water-power by several factories. Its greatest discharge is 342 cubic feet per second; its mean discharge is 37 cubic feet per second; its least discharge is 8 cubic feet per second.

The Park River, which runs through the City of Hartford and enters the Connecticut on the west side, is used as a water-power by mills in Hartford and several places above. Its greatest discharge is 2,308 cubic feet per second; its mean discharge is 139 cubic feet per second; its least discharge is 25 cubic feet per second.

The Hockanum River enters the Connecticut on the east side at the lower end of the survey, about one and one-half miles below Hartford. It is used as a water-power, and is quite an important stream. Its greatest discharge is 6,167 cubic feet per second; its mean discharge is 132 cubic feet per second; its least discharge is 60 cubic feet per second.

BORINGS.

Borings were made at several places, as marked on the maps, to ascertain the depth of the rock in the bed of the river. The tools used were common carpenter's augers of 1½ and 2 inches diameter, attached to a rod of ¾-inch gas-pipe. The pipe was in lengths of 8 feet, with threads cut upon the ends, so that they would screw into an ordinary wrought-iron coupling and abut together within it so as to make a firm joint and give an exact length of pipe to serve as a measure of depth. The head of the auger was also fitted with a corresponding thread to screw into the coupling.

A wooden cross-handle was used for turning the auger and pipe from the top. This passed through an eye or socket with a short stem, upon the lower end of which was a screw-thread fitting into the couplings.

The apparatus for withdrawing the auger consisted of a shears, formed of three poles lashed together at the top and provided with blocks for hoisting out the rod. Where the ground was soft these poles were drawn down so as to be forced into the ground, so that a lever was used to withdraw the rod in some cases.

This apparatus worked very well when the auger was withdrawn sufficiently often, but it was difficult to impress the necessity of this upon the assistants, and the apparatus was frequently injured by the sticking of the auger when bored too far to draw easily.

The material bored through was also in some cases very difficult. In many places a quicksand filled up the hole as fast as bored, and in others the material was of great

hardness. As it was not thought of sufficient importance to go to the expense of lining the holes with pipe, to prevent filling in, some of the borings were abandoned before reaching the rock. It is believed, however, that they are sufficiently deep to show the character of the river-bed.

Respectfully submitted.

THEO. G. ELLIS,
Civil Engineer.

Gen. G. K. WARREN,
Maj. of Engineers, U. S. A.

X 15.

NEW HAVEN HARBOR, CONNECTICUT.

The dredging which was in operation at the time of my last annual report, (August 30, 1873,) under the appropriation of $20,000, approved March 3, 1873, was continued until the proposed improvement was completed.

In this harbor the mean rise of the tide is 6 feet. The object of the dredging was to obtain a depth of 16 feet at mean low-water in a channel 200 feet wide, over the bar between Fort Hale and the light-house, where the available low-water depth was previously 11 feet. This was accomplished before the funds were exhausted, and the channel between Long Wharf and Belle Dock, dredged in 1871, was increased in width 30 feet. The channel of 1871 was supposed to be 100 feet wide and 13 feet deep at mean low-water, but an examination after last year's work showed an available width of but 110 feet, which points to the conclusion that the previous width was over-estimated. The depth had not decreased from 13 feet, and the sides of the channel were well defined.

The amounts removed during the past fiscal year are as follows:

	Cubic yards.
From the bar below Fort Hale	67,762
Between Long Wharf and Belle Dock	11,193
Total	78,955

The result of the dredging on the bar below Fort Hale is not altogether satisfactory. An examination of the channel two months after completion showed results notably different from those to have been expected from examinations made during the progress of the work and from the amount removed, in that the depth should have been 17 feet, while the average of the soundings was but 15 feet. Owing to the excessively soft nature of the material of this bar, it is unsafe to premise a great duration of the channel dredged. No estimates for further improvements there will be submitted until a reasonable degree of permanence becomes assured.

A jetty was commenced on the beach south of Fort Hale, for the double purpose of arresting sand that might drift out on the bar and to cause a breach in the ditch of the fort to close up.

The rock used was that taken from Luddington Rock, and some piles were driven to aid in depositing it. Before the jetty was completed it had succeeded in closing the breach by the action of the natural forces, and it will probably be permanent.

LUDDINGTON ROCK.

The contract for the removal of Luddington Rock to a depth of 16 feet below mean low-water was awarded to Mr. J. F. Ward, of Jersey City, for the sum of $11,000. Work was not begun until the favorable season

was well advanced, and after commencement various delays, caused by incompleteness in the preparations or by accidents, prevented any great progress. A few holes were drilled, but before they were ready for blasting the fall storms had set in. Mr. Ward, however, professes a desire to accomplish the removal of the rock, and has asked for a three months' extension of the contract. No payment is to be made for removing this rock till it is all removed.

It is probable that all the work done on this rock has not yet resulted in the removal of the highest point, 10.4 feet below mean low-water level.

No appropriation was asked for the present year.

The report of Mr. H. N. Babcock, assistant engineer, who superintended the operations in New Haven Harbor during the last year, is transmitted herewith.

New Haven is in the New Haven collection-district, and is a port of entry.

The amount of revenue collected during the fiscal year ending June 30, 1874, was $326,910.88.

Financial statement.

Balance in Treasury of United States July 1, 1873	$40,000 00
Deduct amount expended in fiscal year 1872–'73	854 11
Amount expended during the fiscal year ending June 30, 1874	18,252 58
Amount available July 1, 1874	20,893 31

Report of Mr. Henry N. Babcock, Assistant Engineer.

ENGINEER OFFICE, UNITED STATES ARMY,
Newport, R. I., January 19, 1874.

GENERAL: I have the honor to submit the following report on the improvements in New Haven Harbor, made under your direction during the season of 1873:

DREDGING.

On the 5th of May Messrs. H. N. & A. J. Beardsley resumed the work of dredging on the bar below Fort Hale at the point where they left off in the fall of 1872. At this time one cut of 25 feet width had been made through the bar, and an additional one of 35 feet width about one-third way from the upper end. The Messrs. Beardsley continued working until the 21st of June, finishing this second cut and making another on the east side of the first to straighten out the channel, which was somewhat irregular.

During May they removed 16,641 cubic yards of mud, and during their work in June 24,137 cubic yards, making a total of 40,778 cubic yards during thirty-four working days; an average of 1,200 yards a day. The amount paid them was $8,045.49, the contract-price being 19$\frac{7}{10}$ cents per cubic yard.

The Messrs. Beardsley had five scows in use; two of 214.5 cubic yards contents each, one of 103.4 yards, and two of 56 yards each.

On May 14 the Atlantic Dredging Company began work, under contract for 1873, at 17$\frac{1}{2}$ cents per cubic yard, and continued working on this bar until September 15.

They removed during the respective months as follows:

	Cubic yards.
May	11,135
June	23,478
July	32,643
August	20,416
September	14,703
Total	102,375

This, distributed through eighty-eight working days, makes an average of 1,164 yards per day. Two scows, each containing 312 cubic yards, were employed. From the cut made in 1872 there were 20,629.8 cubic yards removed, making the total amount of material taken from the channel 163,728.8 cubic yards, giving an average depth of cut of 3.88 feet, the length being 5,700 feet and the breadth 200 feet. I was obliged to carry the channel about 1,400 feet farther south than I could trace the cut

of 1872, in order to reach a 16-foot depth. I was unable to learn the cross-range by which the work of 1872 was started. The range fixing the south end of the cut as at present is a line from the cupola of the Seaview House, West Haven, to a point half way between two barns on the brow of the hill beyond, and bears nearly due east and west. The rest of the cut of 1872 was quite well defined, and followed without difficulty. The dredges were ranged on line by oyster-stakes forced into the bottom. These had frequently to be renewed, but were the only satisfactory ranges we could procure. I had one tide-gauge on the shore at Fort Hale, and another about two-thirds way down the cut, fastened to a scantling, which was driven into the mud and held upright by rope-guys radiating off to three stones sunk about 15 feet from the bottom of the gauge. I attached a red flag to this gauge, and it remained till near the close of the work, when it was run over in the night. Part of the time the gauges had to be read by glasses. Soundings were taken generally at the close of each day's work when the weather was suitable. The average of these soundings quite uniformly exceeded the required depth, being occasionally as great as 18 feet; but it was noticed that whenever these soundings were left for two or three days the average was somewhat less.

The mud removed was exceedingly soft, none of it being firm enough to step on, and some so thin as to level itself in the scows; that taken from the ends of the cut appeared in general to have less consistency than that from the middle.

The mud frequently came up full of young clam-shells, never living; it was dark and free from sand, and dried quite hard. The depth of this mud on the bar I could not ascertain. I have frequently seen the dredge's spud—a 40-foot beam—sink down within 10 feet of the water-level where the water was no more than 18 feet deep.

A survey was made in the early part of November to ascertain the condition of the channel after the work. The results of this survey have been transferred to the tracing of the survey of New Haven Harbor of 1871 and to the tracing of the map of the dredged channel after work of 1872. The depths, instead of being excessive, were found almost uniformly too small. The average depth on the line of the cut before work, taken from the map of 1871, appears about 13 feet, and the average depth of material removed—3.38 feet—ought to give a general depth of nearly 17 feet, whereas the survey shows only about 15 feet. This is perhaps only to be expected from the softness of the material; but I do not consider that all can be due to washing in from the sides, as they are yet tolerably well defined; probably it may partially result from a subsidence of the surrounding bottom and a consequent elevation of the bottom in the cut. The gauge used on the survey was one of those used during the dredging, and was referred to the bench-mark at Fort Hale.

The available depth of the channel at the time of the survey was 14.5 feet at mean low-water; but it is impossible to say whether or not it has yet attained a condition of permanency. Before the channel can be of use it must be buoyed; probably a black buoy on the west side at each end and a red buoy on the east side in the middle. The cut ranges between Southwest Ledge and East Rock; but this alone is not definite enough for so narrow a channel. After the completion of this work the Atlantic Dredging Company moved their dredge up the harbor, and made one cut 35 feet wide on the southeast side of the cut made in 1871, from Long Wharf to Belle Dock, removing 11,193 cubic yards in ten working days.

The old cut here was found quite well defined, the mud was much stiffer than that down the harbor, and at the upper end was too hard to be removed with the ordinary mud-buckets. From some of it I washed about 50 per cent. of fine sand and broken shell. Probably all above the west end of the New York, New Haven and Hartford Railroad coal-docks should be mentioned as sand in specifications. A survey made after the completion of the work shows the dredged channel to be 110 feet wide, instead of 135 feet, as it should be if the old cut had been 100 feet wide.

The results of this survey have been copied on the tracing of the map of the upper part of the harbor.

The tide-gauges used were connected with the bench-mark on Long Wharf.

I do not consider it desirable to continue the widening of the channel below Fort Hale any further, at least until the permanence of the present work becomes established. For the present the widening of the channel from Long Wharf to Tomlinson's Bridge would be of more general use than the same amount of work in any other place; after that, from Long Wharf south. I submit estimates for the former.

To make channel from Long Wharf to Tomlinson's Bridge 200 feet wide and 13 feet deep will require the removal of—

60,000 cubic yards mud, at 20 cents	$12,000
12,000 cubic yards sand, at 50 cents	6,000
For superintendence, &c	2,000
Total	20,000

The widening should be on the northwest side of the present channel from Long Wharf to the coal-docks, and above the coal-docks on the south side.

LUDDINGTON ROCK.

On the 20th of June Mr. J. F. Ward, contractor for the removal of the rock, sent out a schooner with apparatus to build a platform over the rock.

Mr. Ward's plan of operations was to set up tripods of railroad iron over the rock, sling spars between the tripods, and build the platform across the spars, the floor to be above extreme high-water. The rails of each tripod were fastened by a steel pin through the top, which was held by lashings. When a half-dozen tripods had been put up the schooner drifted into them and overturned them; the work then had to be repeated. Mr. Ward's idea at first was to use hand drilling. After this proved ineffectual, he set up an Ingersoll drill on the platform, and used steam from the boiler of a towboat which he was then employing. Afterward he had a small upright boiler on the staging, which was too small to keep the drill supplied, and occasioned considerable delay in waiting for steam. Between the time taken for preparation and building the staging, and that occupied in making actual and contemplated changes in the working force and in taking inventories, the best part of the season was consumed, and the result of the whole work is only the drilling of about twenty-five holes to a depth of 17 feet below low-water. The smallness of this result I regard as not so much due to the plan of the work as to the manner of carrying it out.

The platform and tripods are removed for the winter. Mr. Ward intends to begin again as soon as the weather will permit, and carry out his contract, if possible.

While the platform was standing, on account of the ready means of locating soundings accurately, I made a survey of the portion of the rock covered by it. I located the tripod heads, and, stretching a graduated line between them, sounded at every 5 feet, and oftener where there was a decided rise or fall of the bottom. A map of this survey was made on a scale of 5 feet to the inch, which compares sufficiently well with that made after the work of 1872.

The following statistics were published by the collector of port at New Haven:

	1873.	1872.
Value of merchandise imported	$10,463 40	$932,407
Value of merchandise exported	307,000 00	269,925
Total revenue receipts	350,546 00	227,369
Number of foreign vessels entered	104	

The total revenue collected at other ports in the State (Connecticut) in 1873 amounted to but little over $66,000.

Very respectfully,

HENRY N. BABCOCK.

Gen. G. K. WARREN,
Major of Engineers, U. S. A.

X 16.

MILFORD HARBOR, CONNECTICUT.

A survey of Milford Harbor was made in the fall of 1872, and described in my special report dated December 24, 1872, which was printed as part of Ex. Doc. No. 107, Forty-second Congress, third session, and also incorporated into the report of the Chief of Engineers for 1873.

In that report the following estimates were submitted:

For a breakwater at Welch's Point	$67,000
For protecting the east shore by jetties	5,500
For a jetty at the mouth of the Wepanwog	5,500
For dredging the bar at the mouth of the Wepanwog, 100 feet wide by 4 feet deep at mean low-water	7,000
Total	85,000

The title of the appropriation of $5,000, approved June 23, 1874, viz, "for the improvement of Milford Harbor, Connecticut," leaves it free to be applied as deemed best, but the smallness of the amount excludes the first named from consideration. The other estimates have for their object the facilitating of the local traffic.

The appropriated money would be sufficient to cut a channel 80 feet wide, 4 feet deep at mean low-water, through the bar, and this method of expenditure would undoubtedly produce the most immediate and visible results. But the combined effect of the erosion of the east bank and of the ebb-scour from the Wepanwog River would soon fill up any small cut, and leave the work to be repeated. Both the other improvements must be made before or at the same time with the dredging, to leave the increased depth permanent. The present depth of the channel is one that it has attained as an equilibrium of the depositing and scouring actions of the water, and is comparatively permanent; so, until some change in the depth is produced, the scour is at a minimum. The erosion of the east bank is not affected by the condition of the channel above, but with every southerly storm it throws the *débris* of the bank out on the present bar, increasing the distance across it.

The action against the east shore of the harbor being, then, the more energetic, it is proposed to devote the appropriation to the prevention of further erosion by building out jetties between high-water and low-water to the high-water level, and at intervals of 100 feet apart for a distance of 2,100 feet along the shore. This, it is anticipated, will stop the principal source of the bar at the entrance to the river, and leave future appropriations to be expended effectively toward its improvement.

The estimates made for building jetties and dredging were $18,000, leaving $13,000, in addition to the present appropriation, necessary to complete this improvement. This amount could be expended economically in the next fiscal year.

Milford is in the New Haven collection-district. New Haven is the nearest port of entry. The amount of revenue collected there during the fiscal year ending June 30, 1874, was $326,910.88.

Financial statement.

Amount appropriated by act approved June 23, 1874	$5,000
Amount available July 1, 1874	5,000
Amount required for the fiscal year ending June 30, 1876	13,000

X 17.

HOUSATONIC RIVER, CONNECTICUT.

The dredging which was in operation at the time of my last annual report, (August 30, 1873,) under the appropriation of $10,000, approved March 3, 1873, was continued till the fund was exhausted. The object sought in this river is to secure a draught of 7 feet at mean low-water over the shoals and bars. This was practically accomplished with the last appropriation, with the exception of the bar at the mouth. To secure here any permanent increase of the present depth (5 feet at mean low-water) is a very expensive work at best, and I have preferred expending the money at other places first, and waiting the result of our efforts to deepen the water on other similar estuaries before trying here. The mean rise of the tide at the mouth of the Housatonic being 5¼ feet, there is no difficulty for vessels to cross the bar at high-tide, but it is very desirable to cross at the beginning of the rising tide, so that the flood can be carried up to Derby, otherwise the time of two tides might be required in passing the length of the river. A similar effect to deepening the bar at the mouth can be secured to navigation

by deepening the bars at and near the head of navigation, so that they can be passed at half-tide, but these up-river bars are also much subject to the river freshets, and will require annual attention. Work upon the uppermost cannot be relied upon after heavy freshets. The new appropriation for this river will probably be needed in redredging some of the upper bars and in widening, straightening, and deepening the channel.

The work done the past fiscal year was as follows:

Locality.	Cubic yards removed.	Depth at mean low water.	Width available.
		Feet.	*Feet.*
At Crofut's Bar	10,197	7	40
At Drew's Bar	5,052	7	80
At Mill Bar	17,019	7	130
At The Ballast	2,246	7	150
Total	34,514	.....	.....

In connection with this improvement a survey was made from Derby Docks down to and including Drew's Rock and Bar; then an interval of about three and one-half miles of unobstructed river was passed by, and the survey continued from above Mill Bar down to the New York and New Haven Railroad bridge, where a connection was made with the survey of the previous year, which extended to the mouth. The map of the river (in two sheets) from this last survey, on a scale of 200 feet to the inch, is sent herewith. The first surveys of the bars made in 1871 were disconnected, which made a resurvey desirable, which was further needed to ascertain the changes in the river-bed and the results of our operations.

The survey and superintendence of the improvement during the last fiscal year was done by Mr. H. N. Babcock, assistant engineer, whose report is transmitted herewith.

The appropriation of $10,000, approved June 23, 1874, will probably do all that the importance of the navigation of this river will at present justify, but it is recommended that $5,000 be appropriated for the fiscal year ending June 30, 1876, to provide for removing such obstructions as may recur.

In view of the contingent character of the work hereafter to be done upon this river, it is best that the work be done by hiring a dredge by the day, or in some other way, as the necessity for the work arises, and not attempt to make a contract, where the uncertain conditions furnish no basis for a fair agreement for any definite length of time in advance.

Housatonic River is in the Fairfield collection-district. The nearest port of entry is Bridgeport, where the revenue collected during the fiscal year ending June 30, 1874, amounted to $3,584.12.

Financial statement.

Balance in Treasury of United States July 1, 1873	$10,000 00
Amount in hands of officer and subject to his check, (including $104.24 percentage due on contracts not yet completed)	3,396 54
Amount appropriated by act approved June 23, 1874	10,000 00
Amount expended during the fiscal year ending June 30, 1874	13,169 61
Amount available July 1, 1874	10,226 93
Amount required for the fiscal year ending June 30, 1876	5,000 00

Report of Mr. H. N. Babcock, Assistant Engineer.

ENGINEER OFFICE, UNITED STATES ARMY,
Newport, R. I., June 23, 1874.

GENERAL: I have the honor to submit the following report of operations in connection with the improvement of Housatonic River, Connecticut, during the year 1873.

The dredging on this river began the 13th May, under the superintendence of Mr. W. W. Starr, jr., assistant engineer, and passed into my hands on the 1st of June.

During the months of May and June, the contractor for the work, Mr. G. H. Ferris, of Brooklyn, N. Y., removed from Two-Mile Island Bar 20,385 cubic yards: the dredge was then transferred to the bar immediately below Drew's Rock, from which 5,052 cubic yards were removed up to the 15th July, when the dredge was set at work at Mill Bar, removing up to the 14th August 17,019 cubic yards. The remainder of the month of August was spent at Crofut's Bar, from which 10,197 cubic yards were removed; the work was then finished by the removal of the "ballast," which occupied until the 11th September, and required the removal of 2,246 cubic yards. The total amount excavated in the river during the year was 54,899 cubic yards, during 100 working-days, an average of 550 cubic yards per day. The material removed at Two-Mile Island Bar and at Drew's Bar was hard sand; that at Crofut's Bar and Mill Bar was in places dark-colored, fine, and quite soft; the ballast was found to consist of a nucleus of small stones, around which a quantity of compacted shells and gravel had gathered.

The results of the work have been as follows: At Two-Mile Island Bar, a channel was made 7 feet deep at low-water and 80 feet wide; this channel was cut according to ranges laid out in 1872, and as two cuts of 20 feet width each had, by June 1, already been made close to the east shore, it was necessary to make the other two parallel and adjacent; this left the south end of the channel too far to the east to meet the line of deepest water below, so a wedge-shaped cut was made on the west side of the channel as laid out and running about 50 feet farther down stream. This brought the cut to the deepest part of that cross-section of the river. Had time and means permitted, it would have been well to have continued this channel about 500 feet farther down stream; but as it had already considerably exceeded the limits marked out, and as a more pressing exigency existed at Drew's Rock, the dredge was removed. Opposite the upper end of Two-Mile Island, and near the south end of the dredged channel, Turkey Hill Brook empties into the river; there seems a tendency to form a shoal at this point; but, with no record of the condition farther back than last summer, the rate of formation cannot be estimated; the stream is not a large one.

Since the construction of the Drew's Rock embankment, the shoal on the east side has extended up in a point to about 60 feet south of the rock; the current ran around the rock, cutting into the shoal ground just east of the newly-formed bar, then back between the point of the bar and the rock, and turned off again down stream, thus describing rather more than a complete S; the current of the flood-tide was not quite so crooked. Owing to this complexity of current as well as to the narrow and crooked condition of the channel, it was quite difficult for boats to pass the rock safely without running on the bar. I was instructed to cut off the point of this bar rather than to cut a channel through it. This was done in an oblique direction to a point about 200 feet below the rock, and to a depth of 7 feet at low-water. This improvement was appreciated at once, and I was unable to learn that any difficulty in passing the rock had since been experienced.

On the 15th July, the dredge was removed to Mill Bar. The proposed improvement here was to widen the cut of 1872 at the curve in the channel. This was done by making two cuts across the vertex of the curve, and then cutting off the points at either end of those cuts. A small point projecting from the meadows on the east shore just above the north end of the cut was also removed. On the southwest side of the channel, the water is very shallow, and in places low water leaves the bottom bare. That part of the flood-tide that runs up over the shoal ground, instead of turning with the bend in the channel, tends to run obliquely into it. This will probably wash down the sides of the channel more or less, but it cannot well be avoided. At Mill Bar, the river suddenly widens to about double its width above, and the channel crosses quite sharply from the west to the east side of the river. It was in the curve at the east end of this crossing that the main obstruction lay. Farther back than ten years ago the channel was between Long Island and Pope's Flat. In the spring of 1864, the ice blocked between these two meadows, and turned the main body of water against the east shore, where the present channel was formed. It is impossible to say that a repetition of similar circumstances may not divert the channel to its original course. Between Long Island and Pope's Flat, there is now in places as much as 12 feet of water, but there is a shoal at each end of the channel. The great development, at this point in the river, of flats bare or nearly bare at low-water, must be regarded as a decided disadvantage; however much it may increase the tidal basin and consequent scour below, it cannot but have a bad effect at times when the river is unusually

swollen by diffusing the action of the freshet and forming a place of deposit for any material then held in suspension.

The river is wider at Mill Bar than at any other point above the mouth. In the old channel the tide flows very rapidly and keeps it from filling. The dredging made the new channel 200 feet wide at the curve and 120 feet wide elsewhere.

On the 14th August, the dredge was removed to Crofut's Bar, a shoal formed across from the upper end of Wooster's Island to the west shore. The channel east of the island is very shallow. Crofut's Bar had about 5 feet over it at low-water, though, on account of the narrow and crooked course of the channel, hardly that depth was available. A cut was made 40 feet wide and 7 feet deep at mean low-water; but a small amount of the appropriation remained, so the work had to be stopped at this width, in order to leave enough for the removal of the "ballast." Very few, if any, of the boats running to Derby draw over 7 feet of water; and as Crofut's Bar was passable at half-tide to any such, it was not a very serious obstacle; however, it appeared to demand attention quite as much as any point above the New York and New Haven Railroad bridge.

On the 2d September the dredge began work on the "ballast," and by the 11th succeeded in removing the obstruction to a depth of 7 feet. The "ballast" lay about 2½ feet below low-water in the middle of the channel, about a mile below Stratford, and was not buoyed; there was sufficient room and depth to pass on either side, and it could not be a serious obstacle in daylight to any one acquainted with the river; still, its removal must be a satisfaction to all concerned. This done, Mr. Ferris's dredge was discharged; the contractor throughout displayed a willingness to comply with the terms of his contract, and forwarded his work with commendable energy.

There was at this time about $400 of the appropriation left, and with this it was deemed desirable to make surveys of the dredged channels.

SURVEYS.

On the 1st October, with the assistance of Messrs. C. L. Howes and W. C. Graham, assistant engineers, and a party of three boatmen, I began a survey of the river, extending from Mill Bar to the New York and New Haven Railroad bridge. A traverse-line was run on both sides of the river, and the soundings all located by intersecting sights from two transits at stations on the shore. Tidal observations were taken, and high-water and low-water recorded day and night for two weeks. There was a box tide-gauge belonging to the work, which we fastened to a dock at Mill Bar; a brass clamp was made, which could be attached to the indicator of the gauge, and to the end of this clamp a tube, large enough for the play of a lead-pencil, was fixed; then, with the clamp fastened to the indicator, and a very light elastic passed over the head of the pencil to keep it against the face of the gauge, the height of high and low-waters during the night could be distinctly read in the morning by the trace of the pencil. The place of observation was pretty well sheltered from the waves, and the pencil-marks had to be read and washed out before another tide was recorded; the indicator stood 2.7 feet above the level of the water. A bench-mark, consisting of a copper bolt, with a cross filed in the head and leaded into the rock, was established at a point on the east side of a low, rocky hillock, just south of the mouth of Peck's Creek; the bench-mark is 7.544 feet above the observed mean low-water. Unfortunately, during the whole survey, the river was in a state of freshet, making the mean of the observed low-waters about 0.7 foot higher than a true mean low-water. The observed mean rise and fall of tide was 4.36 feet.

As soon as this survey was finished, one was begun extending from Derby Dock to and including the dredged ground below Drew's Rock.

Captain Edwards's bench-marks, established in 1871, were used on this survey. The sounding-stations were connected by triangulation as fast as they were needed, and after the soundings were completed a traverse-line was run as far as the limited time would admit of. A tide-gauge was set up at each of Captain Edwards's bench-marks, one at Derby Dock and one at Drew's Rock. The freshet was found to have raised the river 2 feet at the upper gauge and 1 foot at the lower gauge, where the river is much wider, making the slope greater than the ordinary slope by 1 foot in this distance. The difference of height, 1 foot, was divided proportionally to the distance from one tide-gauge, and this proportional amount was added or subtracted in reducing the soundings, according to the tide-gauge used—added in case of the Derby-Dock gauge and subtracted from that at Drew's Rock. Maps embodying the results of both these surveys have been made on a scale of 200 feet to the inch and submitted.

FUTURE IMPROVEMENTS.

With regard to the necessity of further improvements, the river is at present more easily navigable over its entire length below Derby than over the bar at its mouth. Indeed, with the exception of places where work has been done, I could learn of no locality in the river where shoals were very troublesome. At the upper end of Oronock Meadow, about a mile above Mill Bar, the greatest depth is about 6 feet, but

the channel there is quite wide and is not yet a serious obstacle. Any work elsewhere than at the mouth could probably be done to greatest advantage in widening last year's cut at Crofut's Bar, and in extending the cut at Two-Mile Island about 600 feet down stream. Undoubtedly, work could be done at any time near the docks at Derby and Huntington, which, if not necessary, would be appreciated.

There are now in your possession maps or tracings of maps of the Housatonic River from the villages of Birmingham and Derby to the sound, with the exception of a length of about three and one-half miles between Drew's Rock and Mill Bar. There is no improvement at all urgently needed on this section, but a survey of it would add to the completeness of your information about the present condition of the river.

It is not easy to find a wholly suitable dumping-ground in the river. Unless the late freshets have filled it considerably, some material could be deposited at high-water behind Two-Mile Island, some might be placed behind Forster's Island, and some opposite Drew's Rock. It will be advisable to extend the dumping-ground at Drew's Rock but very little farther north, as the separation from the channel becomes less marked; hence it could not be used much at low-water. All the dumping-grounds in the river are most available at or near high-water, at which time it would be desirable the dumping should mainly be done. This would necessitate the employment of at least five or six scows capable of dumping in 5 feet of water, and a tug-boat drawing no more. If future work be contemplated in this river, above the New York and New Haven Railroad bridge, I should recommend that a positive requirement to this effect be inserted in the specifications.

I am, general, very respectfully, your obedient servant,

H. N. BABCOCK.

Gen. G. K. WARREN,
Major of Engineers, U. S. A.

X 18.

BRIDGEPORT HARBOR, CONNECTICUT.

The improvement of this harbor was begun by me in 1871. That year work was mainly confined to building a jetty or breakwater, perpendicular to Long Beach, on the east side of the harbor. It is designed to arrest the movement of the littoral sand, and to cause a greater portion of the tide to flow over the channels across the bar.

This jetty was increased in length in 1872, and at the end of the fiscal year, June 30, 1873, had been extended 1,380 feet from the beach. No further extension has since been made, as it was thought now long enough to arrest the littoral sand, and allow of the removal of the inner bar without any apprehension that it would be re-formed. Some dredging was done in the years 1871, 1872, and 1873, from means furnished by former appropriations, but the whole amount of the appropriation of $30,000, approved March 3, 1873, was expended in dredging on the outer and inner bars, in the channel heading up to the wharves, and in the basin below the first bridge. A wreck was also removed.

The dredging here is carried on so as to make a depth of at least 9 feet at mean low-water; the mean rise of the tide being 6.65 feet.

The report of the assistant engineer superintending the last year's operations is sent herewith. He has also made what we have every reason to think is an accurate map. The one I had made in 1871 proved to be full of errors.

The improvement by dredging during the past fiscal year has been very apparent and gratifying to all concerned. A very large increase was given to the capacity of the basin just below the first bridge; a very considerable widening and straightening of the channel was made thence down to the inner bar, and so much of the inner bar was removed that the least width of channel there is now 400 feet. All the improvements on the inner bar, and inside of it, have the shelter of the breakwater, and are permanent. It will be desirable to further widen the channel-way above, if means are furnished.

At the outer bar, the channel has been dredged to a width of 150 feet and a depth of about 10 feet at mean low-water. The breakwater and the dredging on the inner bar have probably considerably increased the current on the outer bar, and this will help to maintain the dimensions of the channel now dredged, The channel formerly dredged here seems to have subsequently silted up. It is very desirable to gain more width at this place; but, in dredging for this purpose, care should be taken to not carry this to an extent that will cause the bar to shoal.

With the recent appropriation and the funds on hand, it is recommended to confine the work to dredging at points most needed, to be carried on by contract with the lowest responsible bidder.

The extension of the breakwater will some time hereafter be necessary, and it is probable that a change of direction more to the south will be better than to continue the present direction. There are some who think the effect of this breakwater may be to make the channel go west of the light-house; but it is more probable that, as it is extended, the water will deepen about the end of it, and tend to draw the channel toward itself. No effect appears yet to have been produced at the end of the breakwater. Although it is believed that the channel, after the improvement which the means at present available will allow, will meet present wants; yet, as there are contingencies in a new improvement like this, which may require additional dredging after storms, and a farther extension of the breakwater, an appropriation of $20,000 is recommended for the next fiscal year.

Bridgeport is in the Fairfield collection-district and is a port of entry. The amount of revenue collected during the fiscal year ending June 30, 1874, was $3,584.12.

Financial statement.

Balance in Treasury of United States July 1, 1873	$30,000 00
Amount in hands of officer and subject to his check, (including $1,747.86 percentage due on contracts not yet completed)	7,120 59
Amount appropriated by act approved June 23, 1874	20,000 00
Amount expended during the fiscal year ending June 30, 1874	33,197 61
Amount available July 1, 1874	23,922 98
Amount required for the fiscal year ending June 30, 1876	20,000 00

Report of William W. Starr, jr., Assistant Engineer.

ENGINEER OFFICE, UNITED STATES ARMY,
Newport, R. I., April 30, 1874.

GENERAL: I have the honor to submit the following history of the improvements made in the harbor of Bridgeport, Conn., from the time I took charge, in 1872, to the present time, with a report upon a survey, and estimates for continuing the improvements.

By act approved June 10, 1872, Congress made an appropriation of $40,000 for continuing the work. July 30, 1872, contracts were entered into with Mr. D. V. Howell, of New York, for supplying the granite necessary for extending the jetty, and with Mr. Sidney F. Shelbourne, of New York, for dredging in the bars, and other points in the harbor. August 28, 1872, in accordance with verbal instructions received by me, I proceeded to Bridgeport, and took charge of the work.

During the fiscal year ending June 30, 1873, Mr. Howell delivered 9,523 tons of stone, which extended the jetty 865 feet, making the total length at the present time 1,385 feet.

During the same time, 28,303 cubic yards of material were removed from the outer and inner bars, and below Cook's Point, giving a depth of 9 to 12 feet at mean low-water, as follows:

From outer bar	5,313 cubic yards fine sand and silt.
From inner bar	11,902 cubic yards sand and coarse gravel.
From below Cook's Point	11,088 cubic yards mud.
Total	28,303 cubic yards.

By act of Congress approved March 3, 1873, $30,000 was appropriated to continue the work. A contract was awarded to Mr. Emory R. Seward, of Albany, N. Y., for dredging, he being the lowest bidder; but Mr. Seward was unable to commence the work at the time required, and refused to sign the contract. The work was given to Messrs. H. N. & A. J. Beardsley, of Bridgeport, Conn., at the price for which Mr. Seward was to do it. Part of the time, Messrs. Beardsley used two dredges. The work accomplished during the season ending January 19, 1874, may be summed up as follows:

From inner bar	38,919 cubic yards sand, gravel, and cobble-stones.
From above and below Cook's Point	14,245 cubic yards mud.
From point below Naugatuck Railroad pier	34,294 cubic yards mud.
From opposite docks, inner harbor	78,293 cubic yards mud.
Total	165,751 cubic yards.

The channel through the outer bar is now 150 feet wide, with a depth of 10 to 12 feet at mean low-water. Through the inner bar, abreast of the outer beacon, (formerly the narrowest part of the channel,) the channel is 400 feet wide, with a depth of 10 to 13 feet at mean low-water. At Cook's Point and the point below the Naugatuck Railroad pier, the channel has been widened from 75 to 100 feet, and other points removed which have long been serious obstructions to navigation. In the inner harbor, where there formerly was a narrow channel-way along the docks, so narrow in many places that a vessel could not wind around at low-water, a portion of the flats opposite the docks has been removed so as to make a channel-way 260 feet wide in the narrowest part, with 9 feet depth at mean low-water. The material removed was at first dumped about three-fourths of a mile west of the light-house, but was afterward taken one mile due south of the light-house, and dumped in from 4 to 5 fathoms of water. Late in the season, the strong fall-winds made it so difficult to reach the dumping-ground without danger of swamping the scows that the material was again carried west of the light-house, distant one mile, and dumped as close to the shore as possible.

In April and May, 1873, tidal observations were made at the lower bridge for a lunar month. Observations were made every ten minutes, night and day. A box-gauge was used. Bench-marks have been established, as follows:

Bench-mark No. 1.—On the top of the southwest corner of the draw-pier of the lower bridge. The point is marked with a copper nail, inclosed in a ring of black paint, and is 7.50 feet above the plane of mean low-water as determined by these observations.

Bench-mark No. 2.—On the northeast corner of the foundation for a soldiers' monument at Sea-Side Park. This point is 23.39 feet above the plane of mean low-water.

Bench-mark No. 3.—On a plug 332.6 feet, south 64° 25′ east of the southeast corner of the foundation for soldiers' monument, and is 13.71 above the plane of mean low-water. This plug was known as station 1 west in the survey subsequently made.

The elevation of the bench-mark on the northeast corner of the soldiers' monument was found, after careful tests, to be 2.9 feet less when compared with the plane of mean low-water than the elevation given by Captain Edwards on his map. Mr. Edwards's mistake doubtless arose from error in leveling, and not in the establishment of his plane of mean low-water; for, so far as other comparisons have been made, our planes have been found to be nearly the same.

In August, 1873, while the work of improvement was going on, by your direction I made a survey of the harbor from the lower bridge to beyond the light-house at the entrance. The map, to a scale of $\frac{1}{2400}$, accompanies this report, and shows the condition of the harbor at the time of survey. The areas deepened by dredging are inclosed by red lines for work done in 1871–'72, and by blue lines for the subsequent work.

Bridgeport, with a population of about 25,000 inhabitants, is a thriving city, rapidly growing in commercial importance. It is the terminus of two railroads, and is on the line of the New York and Boston road. These roads supply the industries of many interior cities and towns with fuel and material, which come to Bridgeport by water, and are there transferred to the cars. These places are consequently dependent to a great extent upon the harbor-facilities of Bridgeport. The principal obstacles to be encountered in entering the harbor are the outer and inner bars. The outer bar is about two miles from the docks. The recent improvements here have given a channel-way 150 feet wide, with 9 to 10 feet of water at mean low-water, where there were formerly but 6 feet at the same stage of tide. It is necessary that the approach to a harbor should be wide enough to allow vessels to beat in, in case of head winds, or to have "sea-room" in thick weather. To give this will require a channel-way through the outer bar at least 300 feet wide, with a depth of 9 to 10 feet at mean low-water. It may be necessary to give even a greater width; so I have made an estimate of the amount of material to be removed for 300, 400, and 500-foot channels. To make a 300-foot channel will require the removal of 20,000 cubic yards of sand from an area of

135,000 square feet. For a 400-foot channel it will require the removal of 45,000 cubic yards from an area of 235,000 square feet. For a 500-foot channel it will require the removal of 70,000 cubic yards from an area of 330,000 square feet. The inner bar is about half a mile inside of the outer bar. The channel-way is at present 400 feet wide, and this width would probably be sufficient were it not for a sharp bend here. The current runs diagonally across the channel, and vessels entering the harbor on flood-tide are liable to be carried on the west or north bank of the channel; on the ebb-tide they are liable to be carried on the opposite side. To remedy this, the width must be materially increased. The material to be removed is sand and gravel. An estimate has been made for increasing the width to 500 and 600 feet. To make the channel 500 feet wide will require the removal of 30,000 cubic yards from an area of 95,000 square feet. To make the channel 600 feet wide will require a removal of 64,000 cubic yards from an area of 205,000 square feet. The channel from the inner beacon to the Naugatuck Railroad pier is, at the present time, but 180 feet wide in its narrowest place. This should be widened to the width of the channel above and below. I have made estimates of the amount of material necessary to be removed to make the channel 300, 400, and 500 feet wide. The latter width is the maximum width between the deep hole at the mouth of the gut and the Naugatuck Railroad pier. To make the channel 300 feet wide, it is necessary to remove 56,000 cubic yards of mud from an area of 220,000 square feet; to make the channel 400 feet wide, it is necessary to remove 157,000 cubic yards from an area of 430,000 square feet; and for a 500-foot channel, it will be necessary to remove 277,500 cubic yards from an area of 770,000 square feet.

Above the Naugatuck Railroad pier is a triangular mud-flat called the "Flat-Iron." That part lying outside of the new dock-lines should be removed. This would require a removal of about 20,000 cubic yards of mud from an area of 75,000 square feet.

The first estimates for the jetty at the mouth of the harbor were for a wall 2,800 to 3,600 feet long. At the present time, it is 1,385 feet long, or about one-half the length of the first estimate. It may be found necessary to extend the jetty when the effect of the severe storms of the past winter are more fully known. It is estimated that to extend it 600 feet farther will require 9,000 tons of stone.

RECAPITULATION OF ESTIMATES.

Outer bar:	
300-foot channel, 2,000 cubic yards, at 25 cents	$5,000
400-foot channel, 45,000 cubic yards, at 25 cents	11,250
500-foot channel, 70,000 cubic yards, at 25 cents	17,500
Inner bar:	
500-foot channel, 30,000 cubic yards, at 25 cents	7,500
600-foot channel, 64,000 cubic yards, at 25 cents	16,000
Between the inner beacon and Naugatuck Railroad pier:	
300-foot channel, 56,000 cubic yards, at 18 cents	10,080
400-foot channel, 157,000 cubic yards, at 18 cents	28,160
500-foot channel, 277,500 cubic yards, at 18 cents	49,950
Flat-Iron, 20,000 cubic yards, at 18 cents	3,600
Jetty, for 9,000 tons of stone, at $3	27,000

SUMMARY OF ESTIMATES.

Outer bar	$17,500
Inner bar	16,000
Between inner beacon and Naugatuck pier	49,950
Flat-Iron	3,600
Jetty	27,000
	114,050
Superintendence and contingencies	12,000
Total	126,050

Very respectfully,

WM. W. STARR, JR.

Gen. G. K. WARREN,
Major of Engineers, U. S. A.

X 19.

NORWALK RIVER, CONNECTICUT.

At the date of my last annual report (August 30, 1873) dredging was in progress in this river under the appropriation of $10,000, approved

March 3, 1873. This work continued until the 8th of October, when the appropriation was exhausted. The total amount removed during the past fiscal year is 19,985 cubic yards, cutting a channel 60 feet wide and 6 feet deep at mean low-water, and extending from the head of the channel dredged in 1872 toward Norwalk.

The object of the work in this river is to obtain a channel of 6 feet depth at low-water from the mouth of the river to the Norwalk docks.

The work already done has carried this channel from a point 1,000 feet above the Danbury and Norwalk Railroad docks to a point 600 feet from the Norwalk docks; and under the present appropriation it is proposed to complete this channel, and, with whatever remains, to excavate the channel both above and below the Washington Bridge to a depth of 6 feet and width of about 80 feet. The rise of high tide above mean low-water averages over 7 feet, and the completion of the ensuing year's work will make a high-water draught of 11 feet available to the Norwalk docks.

In order to realize the full effect of the work already done, and to complete the project for improvement planned upon the survey of 1871, it will be necessary to make the channel 60 feet wide and 6 feet deep at mean low-water, from Gregory's Point to Norwalk. This, it is estimated, can be done for $10,000, and this amount is recommended for the fiscal year ending June 30, 1874.

Since my last annual report this work has been under the superintendence of W. W. Starr, jr., assistant engineer.

Norwalk is in the Fairfield collection-district. The nearest port of entry is Bridgeport. The amount of revenue collected there during the fiscal year ending June 30, 1874, was $3,584.12.

Financial statement.

Balance in Treasury of United States July 1, 1873	$5,000 00
Amount in hands of officer and subject to his check	5,006 41
Amount appropriated by act approved June 23, 1874	10,000 00
Amount expended during the fiscal year ending June 30, 1874	10,000 00
Amount available July 1, 1874	10,000 00
Amount required for the fiscal year ending June 30, 1876	10,000 00

Report of William W. Starr, jr., Assistant Engineer.

ENGINEER OFFICE, UNITED STATES ARMY,
Newport, R. I., May 1, 1874.

GENERAL: I have the honor to submit the following report of operations on the improvement of Norwalk River, Connecticut, during the past season, and an estimate for continuing the improvements. Accompanying this report is a sketch showing where the work was done.

By act of Congress approved March 3, 1873, $10,000 was appropriated for this work.

May 6, 1873, a contract was made with Mr. Emory R. Seward, of Albany, N. Y., to do the dredging, at 45 cents per cubic yard. July 7, Mr. Seward commenced where work had been stopped when the previous appropriation was exhausted, at the point marked A on the sketch.

October 8, the last appropriation was exhausted, and work was stopped nearly opposite Smith's dock at Norwalk, and is shown on the sketch at the point B.

Mr. Seward removed 19,895 cubic yards of mud, gravel, and bowlders, some of the latter weighing nearly a ton each. The channel was made 60 feet wide and 6 feet deep at mean low-water, and was extended 1,480 feet beyond the work of the previous season, and toward the stone bridge.

The material removed was carried from three and a half to four miles and dumped in a deep hole at the mouth of the river. The area deepened by dredging under the previous appropriation is inclosed on the sketch by full red lines. The work done during the past season is shown in colors for each month's work.

To obtain the full benefit of the work already done, it is necessary that the work of

improvement should continue. Estimates of the amount of material to be removed and the cost are therefore submitted.

To make the channel 60 feet wide and 6 feet deep at mean low-water between Gregory's Point and the Washington-street bridge, will require the removal of 10,880 cubic yards of mud from an area of 110,000 square feet.

To make the channel 60 feet wide from the Washington-street bridge to opposite the Danbury and Norwalk Railroad docks at South Norwalk will require the removal of 6,520 cubic yards of mud from an area of 48,000 square feet. To make the channel 60 feet wide from the Danbury and Norwalk Railroad dock to W. Jennings's wharf will require the removal of 15,000 cubic yards of mud from an area of 52,000 square feet. To make a 60-foot channel 6 feet deep through the "Middle Ground" below the stone bridge will require the removal of 12,500 cubic yards of sand and gravel, with occasional bowlders, from an area of 33,000 square feet.

RECAPITULATION OF ESTIMATES.

From Gregory's Point to Washington-street bridge	10,880 cubic yards
From Washington-street bridge to Danbury and Norwalk Railroad dock	6,520 cubic yards.
From Danbury and Norwalk Railroad dock to Jennings's wharf	15,000 cubic yards.
Through the Middle Ground	12,500 cubic yards.

SUMMARY OF ESTIMATES.

10,880 cubic yards from below bridges, at 20 cents	$2,176
21,520 cubic yards to Jennings's wharf, at 30 cents	6,456
12,500 cubic yards from Middle Ground, at 50 cents	6,250
Add superintendence and contingencies	1,500
Total	16,382

Very respectfully,

W. W. STARR, JR.,
Assistant in charge of Norwalk Harbor Improvement.

Bvt. Maj. Gen. G. K. WARREN,
Major of Engineers, U. S. A.

X 20.

PORT JEFFERSON HARBOR, LONG ISLAND, NEW YORK.

The funds available at the beginning of the fiscal year just closed were about $1,700. It was at first thought best to try plowing up this bar to aid the effect of the current, but the amount was too small to expect much good effect, and so it was thought best to reserve the fund till more was added to it.

This June we made another survey, to ascertain the changes, if any, that had taken place; this was made by Mr. Babcock, and his map is transmitted herewith. It shows clearly that the breakwater has thus far accomplished the object intended, and given a permanence to the position of the entrance; for there is no positive change in it during the past year. Such filling at places as has taken place was expected, but the depth over the bar is not materially different. The previous survey seemed to show a slight increase in depth, but it is not confirmed by the last survey, and the differences are probably owing to some slight variations on the plane of water-surface at the different times when soundings were taken. It is not recommended to do anything with the means on hand, but to reserve it for surveys and for contingencies that may arise here.

It would be a valuable improvement if completed as designed, and the foundation of the work is well established.

An appropriation of $35,000 for continuing this work is recommended This will be mainly required for dredging. It will be seen by looking

at my former reports that this bar is formed by the stones brought along the shore from Mount Misery to the east of it. These are as large as paving-stones, and many are composed partly of iron, so as to be nearly one-half heavier than ordinary stones. They resist a current of eight to twelve miles an hour. If removed from the channel, the breakwater will prevent others from being brought into it, and the depth will remain. An extension of the breakwater somewhat will ultimately be required, but this could be avoided beyond the present 9-foot curve if the base of Mount Misery was protected by stone from abrasion by the waves.

Port Jefferson is in the New York City collection-district, and New York City is the nearest port of entry.

The amount of revenue collected there during the fiscal year ending June 30, 1874, is ———.

Financial statement.

Amount in hands of officer and subject to his check	$1,713 95
Amount expended during the fiscal year ending June 30, 1874	204 01
Amount available July 1, 1874	1,509 94
Amount required for the fiscal year ending June 30, 1876	35,000 00

X 21.

PECONIC RIVER, LONG ISLAND, NEW YORK.

At the time of my last annual report the dredging of a channel, to be 55 feet wide and 6 feet deep at mean low-water, was being actively prosecuted, under a contract made with M. F. Brainard, of Albany, N. Y.

The amount available for the work on the 1st of July, 1873, was $13,949.18. There was, besides, an appropriation of $5,000 for this improvement, made by the State of New York.

We began our work just below Indian Island, where there had always been a depth of 6 feet at mean low-water, and carried it on continuously till our means were exhausted. The cut we had made is 8,520 feet long, and the amount of material removed 60,045 cubic yards.

There is left a space of 2,500 feet still in its natural condition, with a mean low-water depth of only 2½ feet before reaching the channel we made (extending up to Riverhead) in 1871.

The work in 1871 was through a very shoal part of the head of the river, and was made 25 feet wide and 4 feet deep at mean low-water.

During the progress of the work in the last fiscal year (the season of 1873) we found that our means would not allow us to make the channel 55 feet wide all the way up, because the original estimate was too small in amount of material to be removed, owing to the mean low-water plane having been taken too high, and owing, besides, to the contract-price exceeding that first estimated. We therefore meant to make a narrower channel, so as to make it extend the whole length of the river. This course was opposed by those having charge of the expenditure of the $5,000 from the State of New York, as they concluded that with this means they could make the desired extension of the channel themselves.

When the contractor for doing this State work was about to begin, after our operations had closed, it was discovered that the State appropriation was not available, and nothing more was done that season.

In the last annual report I made no estimate of funds for continuing the work through the fiscal year beginning July 1, 1874, for I thought

sufficient had already been appropriated. Besides the cost of the survey in 1870, the United States have appropriated $25,000 for this improvement.

How far I am called upon to decide upon the continuation of a public improvement is questionable, but I do not feel justified, on ground of national necessity, in recommending any further appropriation here.

We estimate that about $15,000 additional will carry the channel, 55 feet wide and 6 feet deep at mean low-water, up to a place called Merritt's Bay, a distance of 3,500 feet; that $10,000 would make two cuts through this distance 6 feet deep and 50 feet wide, by throwing the sand alongside the channel; and that $5,000 would make a single cut, say 25 feet wide and 6 feet deep, throwing the material over alongside the channel. This latter has been done, with the appropriation of that amount from the State, during the present season.

I submit, herewith, a report and map, showing the present condition of the Peconic River, prepared by my assistant engineer, Mr. John H. Dager, who superintended the dredging during the past year. Mr. H. S. Van Ingen, assistant engineer, superintended the work done in 1871, and prepared a map of the part then improved, so that there are now on the files of the office of the Chief of Engineers the map of survey made in 1870, another showing the river as improved in 1871, and this last one showing the river as left by the improvement made in 1873. These may be useful some future day in studying the effect of time upon such dredging-operations.

Peconic River is in Sag Harbor collection-district. The nearest port of entry is Sag Harbor. The amount of revenue collected during the fiscal year ending June 30, 1874, was $945.25.

Financial statement.

Balance in Treasury of United States July 1, 1873	$10,000 00
Amount in hands of officer and subject to his check, (including $522.50 percentage due on contracts not yet completed)	4,471 68
Amount expended during the fiscal year ending June 30, 1874	14,061 24
Amount available July 1, 1874	410 44

Report of Mr. John H. Dager, Assistant Engineer.

ENGINEER OFFICE, UNITED STATES ARMY,
Newport, R. I., December 12, 1873.

GENERAL: I have the honor to make the following final report on operations for improving the Peconic River, Long Island, New York, during the year 1873:

Charge of the work was assigned to me by your letter of instructions dated March 15, 1873. The amount of funds available at that time was $20,000; $10,000 having been appropriated by act of Congress approved June 10, 1872, and the remaining $10,000 by an act approved March 3, 1873.

Two contracts were made with Mr. Morris F. Brainard, of Albany, N. Y., for the expenditure of these appropriations by dredging in the channel of this river; the first, at the rate of 24 cents per cubic yard of material removed; the second, for a similar purpose, but a rate of 34 cents per cubic yard.

Work was commenced by the contractor in April, immediately below Indian Island, and prosecuted without interruption until the funds were exhausted.

A channel averaging 55 feet in width at bottom, with such side slopes as an Osgood dredge will leave, was made from the place of beginning to a point above the mouth of Mud Creek, excepting for a distance of 550 feet, where there was a sufficient width and depth of water, making in all a cut 8,520 feet long, and as near 6 feet deep at mean low-water as was possible.

The material removed consisted of mud and sand, combined, in most places, but in some separate, and with an occasional vein of gravel and iron crossing the channel.

At the end of each month a sketch was sent you, showing the location of the work during that time.

All the material removed was towed in scows into the large cove on the north shore of the river, below Indian Island; it was measured in the scows, and in amount each month was as follows:

	Cubic yards.
April, 1873	3,725
May, 1873	8,252
June, 1873	9,794
July, 1873	11,628
August, 1873	3,004
September, 1873	11,232
October, 1873	6,560
November, 1873	5,850
Total number of cubic yards removed	60,045

This amount exceeds the amount estimated in previous reports as necessary to remove from this portion of the river. The greater part of this difference is due to the difference in the low-water planes used. This is explained as follows: The soundings made in 1871 were reduced to mean low-water established from tide-readings made in November and December, at Terry & Wells's dock, at the head of the river, where the river-bottom was nearly bare at low-water, and where, were it not for the river-water, it would have been entirely dry. Since the channel was dredged in 1871, near the docks, the adjacent flats are dry some time before low-water, showing that previous to this improvement there was quite a descent to the river-surface at low-water, and hence the former low-water plane at Terry & Wells's dock was not applicable to the tidal level which the improvement introduced. This explanation is necessary, because the bench-mark established in 1871 was destroyed by fire, and no direct comparison could be made. The contract price was also in excess of the estimated cost, which together with the increase in quantity previously explained prevented the work being extended as far up the river as was anticipated.

It was contemplated at one time to continue our work to a narrower channel, say, of one cut of 25 feet in width, and throw the material to one side of the dredge, so as to make a continuous channel up to the one made in the upper part of the river in 1871; but this course was opposed by the people because there was an appropriation of $5,000 from the State of New York with which to continue the improvement of the river, and this would have been sufficient to make this narrow channel between where we left off and the previous one in 1871.

After the expenditure of the United States appropriation, a contract was entered into by the committee in charge of these State funds for the expenditure of the same; but, before work was commenced, it was found that there was no certainty as to the time when the contractor could get his pay, owing to some informality in the act of appropriation; consequently the contract was annulled.

A continuation of the channel (the same width and depth as we have been making) up to the point marked *x* on the map, at the west end of Merritt's Bay, a distance of 3,500 feet, would require the removal of 39,000 cubic yards, and would cost (if towed away) $15,000, or, if thrown over from the dredge alongside the channel, $10,000. I think a channel 25 feet wide, made by throwing the material aside, and costing $5,000, would be amply sufficient for the small amount of trade by water; and in view of what has been done by the General Government already for the interests of the few business men in Riverhead, they should complete the work by subscription.

Tide-gauges, for the establishment of mean low-water, were located as follows: One below the mouth of Saw-Mill Creek, fastened to a pile driven near the north shore of the stream. (See map.) Another was placed at Howell's dock.

Simultaneous readings were taken on these gauges from June 7 to June 26, 1873, inclusive.

For the establishment of mean low-water, the readings for fifteen consecutive days were used, and give it, on the gauge at Howell's dock, at 0.7 foot. The mean rise and fall of tide on this gauge is 2.70 feet.

Mean low-water, on gauge below Saw-Mill Creek, came at 2.15 feet, and the mean rise and fall was 2.9 feet; zero, on this gauge by levels, is 1.36 feet lower than zero on gauge at Howell's dock. The slope of water between gauges is 0.09 foot.

Soundings were reduced to the plane of mean low-water, established from my observations, up to the west end of Merritt's Bay, marked *x* on map; and for the reduction of those above readings were taken on a temporary gauge at Terry & Wells's dock.

In connection with this report, I submit tabulated high-water and low-water readings taken on the above-mentioned gauges; also duplicate maps extending from below Indian Island to the bridge at Riverhead, and showing the improvement made this season, made from a survey taken in December, and plotted to a scale of $\frac{1}{400}$. Con-

tour-lines of planes of 0, 2, 4, and 6 feet are respectively shown by these colors, viz, black, purple, burnt sienna, and green.

The monthly work is shown in order by colors, as follows: April, 1873, raw sienna; May, 1873, indigo-blue; June, 1873, H.krs green; July, 1873, carmine; August, 1873, ch. yellow; September, 1873, ch. vermilion; October, 1873, bt. sienna; November, 1873, bt. umber.

Soundings are reduced to mean low-water, and are expressed in feet and tenths.

The following bench-marks were established, referring to mean low-water: Top of facing stone of the south side of the cellar-stairs of the store of Skidmore & Vail is 8.9 feet above; northwest corner of Howell's dock is 3.2 feet above.

Very respectfully,

JOHN H. DAGER.

Gen. G. K. WARREN,
Major of Engineers, U. S. A.

Table of high-water and low-water readings taken on gauge at Howell's dock, Peconic River, Long Island.

Date.	Time.	High-water.	Time.	Low-water.
1873.		*Feet.*		*Feet.*
June 7	9.25 a. m.	3.5	3.20 p. m.	1.2½
June 8	10.18 a. m.	3.4	4.12 p. m.	1.2
June 9	11.10 a. m.	3.2½	5.10 p. m.	1.1
June 10	11.35 a. m.	3.6½	6.10 p. m.	0.7½
June 11	12.30 p. m.	3.8½	7.30 p. m.	0.1
June 12	1.15 p. m.	3.0½	8.30 a. m.	0.2½
June 13	2.55 p. m.	3.0	9.25 a. m.	0.4½
June 14	4.10 p. m.	3.4½	10.30 a. m.	0.8
June 15	4.45 p. m.	3.3	11.20 a. m.	0.6½
June 16	5.25 p. m.	3.1½	12.10 p. m.	0.4½
June 17	5.35 p. m.	3.8½	12.30 p. m.	0.5
June 18	6.15 p. m.	3.8	1.15 p. m.	0.6½
June 19	6.55 p. m.	3.8	2.00 p. m.	0.7
June 20	8.00 a. m.	3.3	3.00 p. m.	0.7½
June 21	9.05 a. m.	3.1½	3.55 p. m.	0.8
June 22	10.10 a. m.	3.1	4.30 p. m.	0.6½
June 23	11.15 a. m.	3.1	5.05 p. m.	0.5½
June 24	12.30 p. m.	3.2	6.15 p. m.	1.1½
June 25	12.50 p. m.	3.2½	7.15 a. m.	0.7
June 26	1.45 p. m.	2.8	8.20 a. m.	0.8

NOTE.—The establishment of mean low-water, by the use of any fifteen consecutive readings, comes at 0.7 foot on gauge.

Mean rise and fall of tide, 2.7 feet.

Table of high-water and low-water readings taken on gauge below Saw-Mill Creek, Peconic River, Long Island.

Date.	Time.	High-water.	Time.	Low-water.
1873.				
June 7	9.25 a. m.	5.0	3.35 p. m.	2.4
June 8	10.05 a. m.	5.2	4.20 p. m.	2.4½
June 9	10.45 a. m.	4.8	5.15 p. m.	2.3½
June 10	11.15 a. m.	5.1	5.50 p. m.	2.2
June 11	11.45 a. m.	4.7	6.45 p. m.	1.5
June 12	1.10 p. m.	4.8	7.45 a. m.	1.6
June 13	2.05 p. m.	4.9	8.40 a. m.	2.1
June 14	2.55 p. m.	5.1	9.30 a. m.	2.1½
June 15	3.50 p. m.	5.2	10.20 a. m.	2.3
June 16	4.50 p. m.	5.2	11.00 a. m.	2.1
June 17	5.35 p. m.	5.1	11.50 a. m.	1.9
June 18	6.05 a. m.	5.1½	12.30 p. m.	2.1½
June 19	6.55 a. m.	4.9	1.20 p. m.	2.2
June 20	7.45 a. m.	4.8	2.15 p. m.	2.1½
June 21	8.25 a. m.	4.9½	3.10 p. m.	2.2½
June 22	9.15 a. m.	4.9	3.55 p. m.	2.0½
June 23	10.00 a. m.	5.0	4.45 p. m.	2.4
June 24	10.50 a. m.	4.9	5.40 p. m.	2.3
June 25	11.45 a. m.	4.8½	6.30 p. m.	2.2½
June 26	12.35 p. m.	5.0	7.25 a. m.	2.1

of high-water and low-water readings taken on gauge below Saw-Mill Creek, Peconic River, Long Island—Continued.

Date.	Time.	High-water.	Time.	Low-water.
		Feet.		*Feet.*
6	9.20 a. m.	4.8½	3.35 p. m.	2.3
7	10.00 a. m.	4.9	4.30 p. m.	2.1½
8	10.45 a. m.	5.0	5.10 p. m.	2.2
9	11.30 a. m.	5.1¼	6.00 p. m.	2.3
0	12.20 p. m.	5.0	6.50 a. m.	2.1
1	1.25 p. m.	5.5	7.40 a. m.	2.3
2	2.10 p. m.	4.9	7.25 a. m.	1.9
3	3.00 p. m.	4.8½	9.20 a. m.	1.8
4	3.50 p. m.	4.8	10.25 a. m.	1.5
5	4.45 p. m.	5.1	11.30 a. m.	1.7
6	5.30 p. m.	5.6	12.10 p. m.	1.8
7	6.10 p. m.	5.2	1.00 p. m.	2.8
8	7.00 a. m.	6.0	1.35 p. m.	3.8
9	8.00 a. m.	5.4	2.20 p. m.	2.5
0	9.00 a. m.	5.2	3.30 p. m.	2.4
1	9.55 a. m.	5.1	4.45 p. m.	2.2½
2	10.45 a. m.	4.8	5.55 p. m.	1.8
3	12.15 p. m.	4.8	6.45 p. m.	1.8
4	1.00 p. m.	4.6	7.20 a. m.	1.9
5	1.25 p. m.	4.8	8.00 a. m.	2.0
6	2.10 p. m.	4.9	8.50 a. m.	2.1½
7	3.00 p. m.	4.6	9.30 a. m.	1.2
8	3.35 p. m.	4.8	10.10 a. m.	1.9
9	4.20 p. m.	4.9	10.50 a. m.	2.0
0	5.10 p. m.	4.9	11.40 a. m.	2.1½
1	6.00 p. m.	5.0	12.20 p. m.	2.3

:.—Mean low-water comes at 2.15 feet on gauge, and is 8.9 feet below top of facing-stone of the ide of cellar-stairs of the store of Skidmore & Vail. Mean rise and fall of tide, 2.9 feet.

X 22.

SURVEY OF WOOD'S HOLE, MASSACHUSETTS.

eport submitted December 31, 1873, and printed as part of *Ex.* 84, Forty-third Congress, first session.]

is is one of the surveys directed by the act for improvement of s and harbors, approved March 3, 1873, which has been intrusted 3.

e immediate conduct of it I gave to my assistant engineer, Mr. J. otton, who has, with the aid of other assistants, made the survey thorough, and has prepared a map on a scale of 200 feet to the ; he has also prepared a full report with estimates for improvement red.

e term "Hole" on this part of the coast was applied by the first gators, generally, to a shelter or harbor, and not to a passage-way. term was similarly employed by the trappers in the Rocky Mount- Thus we have in the Vineyard Sound, "Holmes's Hole," "Wood's ," and "Robinson's Hole," and in the far West such sheltered places ig the mountains as "Ogden's Hole," "Pierre's Hole," and the like etimes it happens that the "Hole" is mainly a passage-way or straits the case of Quick's Hole, one of the straits connecting Buzzard',. with Vineyard Sound, and sometimes it is only a harbor, as is the with Holmes's Hole.

ood's Hole, as a deep harbor in Vineyard Sound, is quite distinct from trait connecting it with Buzzard's Bay. But the term is now gen- y applied to this strait as well as to the harbor, and as this is the : where the improvement is required it is the part where the survey

has been made with greatest care. In speaking of it hereafter, the term "Hole" will be used by me as referring specially to the strait.

Wood's Hole, then, separates from the main-land the chain of islands known as the Elizabeth Islands, lying between Buzzard's Bay and Vineyard Sound. The length of this chain of islands is about twenty miles. The main island, next to Wood's Hole, (Naushon Island,) is separated from its neighbor (Pasque Island) by Robinson's Hole. This passage is narrow and obstructed. Pasque Island is separated from the next island to the west (Nashawena Island) by the broad and deep strait known as Quick's Hole. Nashawena Island is separated from Cuttyhunk Island by another very narrow passage.

Besides the serious obstructions at Wood's Hole, which will be described further on, it is, in common with the other straits between the Elizabeth Islands, but in a more marked degree than the others, rendered difficult of navigation on account of the two different derivations of the tides which affect Vineyard Sound. One of these tides enters at the southwest end, between Cuttyhunk and Gay Head, and the other, about four hours later, comes from the northeast, through Nantucket Sound, from Monomoy Point. It thus happens that the tide from the east is coming in between three and four hours after the other tide, which alone affects Buzzard's Bay sensibly, has been going out. In the vicinity of the Hole, therefore, when there is a stand on either side, it is rising or falling fast on the other side, and the distance through the Hole being only about 2,500 feet, the difference of level quickly sets the current in motion through it, and there is scarcely any useful period of slack-water.

Our observations at neap-tide show a head of water forcing the current west, varying from 0 to 1.6 feet, and 0 to 1.6 feet in the opposite direction. These give maximum velocities of 4.26 miles per hour flowing west, and 5.06 miles per hour flowing east, which approximate to those in Hell-Gate, in New York Harbor, where there is also a dual derivation of the tides.

It might at first be supposed that nothing but ledges of solid rock could have for ages endured this unceasing flow of water, but our examinations only show us a hard, compact bowlder-clay. The softer parts of this have been worn away, leaving the large granite bowlders behind, until the latter have completely covered the surface of the mass beneath in the shoal places and prevented further abrasion. These bowlders lie, however, in most dangerous proximity to the water's surface nearly all over the strait, and as they do not completely deflect the current, the latter sweeps vessels directly upon them. The channels (so called, that is, the parts where there is the deepest water and fewest bowlders) are very crooked, and the strait, as a whole, is so dangerous as to be useless to any sail-vessels but small ones, in the hands of pilots familiar with the place. Even with steam, only small vessels of about 8 feet draught can pass it at all times, and for them it is dangerous.

The nature of the obstructions, as above described, presents a hopeful case of improvement compared with the removal of solid ledge.

The bowlders are lying detached, and can be grappled and lifted. In many cases their size is so great as to require blasting. With the removal of the worst of these the improvement will be at once felt, and if it is continued until the clayey surface beneath is uncovered, the latter can be dredged at once; or, if left to time, in all probability the current will then continue to deepen it until it is again protected by the new bowlders which this denuding action may disclose.

In the estimates submitted, the smallest one, $5,000, will remove a

few of the worst rocks that now interfere with the running of the steamboats between New Bedford and Martha's Vineyard. This improvement will be of benefit principally to them. It is much more advisable, however, to appropriate the $22,000 estimated for a more thorough removal of the bowlders. This will be of benefit to a large number of sail-vessels, and a great deal more good can be done with it, in its proportion, than with the smaller sum, because it is a difficult place to operate in, and the necessary preparations will consume a large part of the smaller amount and leave but little to work with. When adequate preparations are once made, it is very desirable to continue the work until it reaches a satisfactory conclusion.

Our estimate further includes a larger sum for continuing the improvement by dredging, and otherwise to enlarge the passage to a capacity adapted to the use of our coastwise sailing fleet, whenever it is advantageous to make the passage through Buzzard's Bay instead of the opposite portion of the sound. It may be too soon to begin this now, but it will ultimately be necessary, and while upon the subject we have made our plans complete and looking toward such final accomplishment. All the partial improvements proposed are, as far as they go, directed toward this final end, while at the same time affording the greatest benefit.

This improvement may truly be called a national one. It is not for the benefit of the special locality. It is for a navigable highway uniting two large bodies of navigable water extensively used by the commercial vessels of the United States, and when thoroughly improved it will tend greatly to a saving of time and diminish the dangers of navigation. The circumstances under which its use is particularly desirable, and the reasons for it in detail, are given in Mr. Cotton's report.

In conclusion I would say that I consider $22,000 as the most desirable amount with which to begin this work.

In 1852 there was an appropriation of $2,500 made for the improvement of Great Wood's Hole Harbor. This was spent in building a breakwater on its northern side to close a passage through which water passed between it and Buzzard's Bay. The report of this operation is found in the annual Report of the Chief of Engineers for 1853. It would appear that the work was left incomplete, as an additional appropriation of $2,000 was solicited. Private parties have, however, since continued the work, and occupied the vicinity, so that the opening is entirely closed at the present time.

Wood's Hole is in the Barnstable collection-district. The amount collected there during the fiscal year ending June 30, 1873, was $3,425.

Very respectfully,

G. K. WARREN,
Major of Engineers, Bvt. Major-General, U. S. A.

Report of Mr. J. P. Cotton, Assistant Engineer.

ENGINEER OFFICE, UNITED STATES ARMY,
Newport, R. I., December 31, 1873.

GENERAL: I have the honor to submit the following report on the "survey of Wood's Hole, Buzzard's Bay, Massachusetts, for the removal of rocks therefrom," made in accordance with your instructions.

The field-work of this survey was commenced June 25, and completed July 30, 1873. The party was organized under Charles R. Mather, civil engineer, as principal assistant, with C. L. Howes and W. P. Jewett, civil engineers, subassistants, and the necessary chainmen, boatmen, and gauge-readers.

An examination of that part of Wood's Hole obstructed by rocks showed that satis-

factory soundings could be made only at slack-water. I therefore concluded to extend the survey to Nobska Point, in Vineyard Sound, so as to include Great Harbor, Little Harbor, and Great Ledge.

The survey was made in the following manner: A traverse line was run from Nobska Point around Little Harbor, Great Harbor, and through the "Hole" to Buzzard's Bay, then by triangulation to the south shore of the "Hole" and thence back to Vineyard Sound. This entire system of traverse was divided up into three polygons; the correctness of the sides was checked by the latitudes and departures of each, and by plotting by chords; the angles were checked by summation. Each angle was read three times.

Tide-gauges were set up at the Government wharf in Little Harbor, at the railroad-wharf in Great Harbor, one in the "Hole" near "Middle Ledge," and one on the wharf in Hadley Harbor, in Buzzard's Bay.

The zero of the gauge in Little Harbor was referred to the United States Coast-Survey bench-mark, which is on a large bowlder on the shore at west end of a cranberry-marsh, about 1,700 feet west of Nobska light. The letter M cut in this bowlder is 9.73 feet above mean low-water in Vineyard Sound. The zero of the gauge on the wharf in Hadley Harbor was referred to the Coast-Survey bench-mark on a bowlder about 800 feet southwest of Uncatena Point. This bowlder is a very large one, some 200 feet from the high ground. The letter M cut on top of it is 8.85 feet above mean low-water in Buzzard's Bay.

Simultaneous observations on these four gauges were taken for four consecutive days, July 30, 31, August 1 and 2, to determine the relation of the water's surface in the "Hole" to that in Vineyard Sound and Buzzard's Bay. The zeros of these gauges were connected by level. It was found by these levels that mean "sea-level" in Buzzard's Bay and in Vineyard Sound was practically the same.

Mean rise and fall of tide in Buzzard's Bay, according to the Coast Survey, is 4.01 feet, and in Vineyard Sound 1.65 feet; our observations for four days, near neap tides, gave the mean rise respectively 3.25 feet and 1.05 feet. Mean "sea-level" being the same in both, mean low-water in Buzzard's Bay would be about 1.2 feet lower than mean low-water in Vineyard Sound. In view of this difference in the low-water planes, it would have been better, perhaps, to have reduced the soundings to mean "sea-level," but as in all of our surveys and in all the maps made by the United States Coast Survey mean low-water is the plane of reference, it was deemed best not to depart from this custom.

The soundings in Buzzard's Bay and into the "Hole" to a line joining the east end of Devil's Foot Island and Mink Point were reduced to mean low-water in Buzzard's Bay, and those east of this line to the mean low-water plane of Vineyard Sound.

If the time of low-water was the same in Buzzard's Bay as in Vineyard Sound, this difference of planes to which soundings were reduced might be detected in the depths, but low-water occurs in the sound about two hours after it has commenced to rise in Buzzard's Bay.

The tides at this place, like all places where they have more than one derivation, are quite complex, and the usual terms of flood, ebb, and slack-water, cannot be applied here.

The tide-wave from the ocean, which enters Buzzard's Bay between Cuttyhunk Island and the main-land, has, by reason of the shoaling of the bay and concentration by the shores, increased in height from 3.6 feet at Cuttyhunk to 4.0 feet at the north side of Wood's Hole. When it is low-water at Buzzard's Bay the sound is partially filled by the tide coming in at the east end of the sound, by Monomoy Point, which reaches the sound side of Wood's Hole about four hours later than the one from the west by Cuttyhunk. This difference in derivation and time so modifies the tide on the sound side of Wood's Hole that the mean rise and fall is but 1.65 feet. This difference in the rise and fall of tides in the bay and sound at Wood's Hole gives a head of water on one side or the other of the "Hole" at nearly all times of tide, and consequently a strong current through it. Slack-water occurs between high and low water, instead of those times, and high and low-water on the gauge occurs when there is a swift current through the "Hole."

Those navigating this channel use the terms "west tide" when the current is setting from Vineyard Sound into the bay, and "east tide," when from the bay into the sound. These terms will be used hereafter in this report when speaking of the currents in the "Hole."

Observations for velocity and direction of these currents were taken for an "east" and "west" tide. The floats used were of pine, 2 inches by 2 inches in section, 5 feet long, and loaded to float in a vertical position; a small wire was inserted in the upper end, and on this a flag 2 inches square was placed, to enable the observers to follow them. The position of these floats was determined every thirty seconds, by the intersection of lines of sight from each end of a measured base on shore; the angles which these lines made with the base were simultaneously measured by observers with a transit. A line drawn through these points shows the direction traveled by the floats,

and the distance between them gives the velocity. The course of these floats shows that the obstructions here (so dangerous to navigation) are not sufficient to direct and control the current. Of fifteen floats let out in 12 feet and upward of water, ten passed over shoals with less than 9 feet, and several of them dragged over bowlders with but 2 or 3 feet on them; five only followed the channels usually navigated.

The maximum velocity of the "east tide" was 5.06 miles per hour, and of the "west tide" 4.26 miles per hour. The greater velocity of the "east tide" is doubtless due to the fact that it occurs when the tide is high in the bay. This gives about 2 feet more depth in the "Hole" than at the time of the "west tide," which occurs when the water in the bay is below mean sea-level.

The observations giving the above velocities were made at time of neap tides. Gauge-readings were not taken in both bay and sound at that time to determine the actual head of water, but at the time of succeeding neap tides they were kept for four days. The greatest head of water in these four days was about 1.6 feet. It was about the same in the "east" and the "west tide." The head and consequently the velocities would be much greater at time of spring tides. A chart of these current observations accompany the map of the survey.

DESCRIPTION OF THE "HOLE" AND ITS CHANNELS.

The name Wood's Hole is generally applied to the harbor of refuge here and the strait connecting the sound and bay. Those using this strait, however, apply the name Wood's Hole to the harbor and the village, and speak of the strait as the "Hole;" these names have this signification in this report.

The "Hole" is about 2,500 feet long and 1,600 feet wide. Great Harbor, at the eastern entrance of the "Hole," has from 30 to 75 feet of water over its whole extent. Vessels drawing 23 feet of water can enter this harbor from the sound.

In 1853 a breakwater 300 feet long and about 6 feet wide on top was built by the Government across a neck of land separating Buzzard's Bay from Great Harbor. It was built to prevent the sand being washed into Great Harbor in time of high tides and storms from the northeast. The amount appropriated for this work was $2,500, but I infer that this amount did not complete it as first designed, as an additional appropriation of $2,000 was asked.

A road has since been built over this neck of land, and the shore at the west end of the breakwater riprapped by private parties. It is now in good repair, and apparently secure.

The entrance to the "Hole" is obstructed by a reef of bowlders extending from Mink Point to Grassy Island, and thence to Devil's Foot Island. This reef is known as Red Ledge, Dry Ledge, and Grassy Island. There is a channel between Mink Point and Red Ledge called Broadway, with 20 feet of water for 150 feet in width; beyond this width it shoals rapidly. This channel is generally used by the boats of the New Bedford and Martha's Vineyard Steamboat Company; but it is not practicable for sailing-vessels, because of the sharp turn necessary to reach the main channel north of Middle Ledge and the strong cross-current. There is a narrow, crooked channel between Red and Dry Ledges with about 7 feet of water; this channel, I believe, is never used.

Middle Channel, between Lone Rock on east end of Dry Ledge and Grassy Island, has about 10 feet depth, at mean low-water, for 100 feet in width; this is the channel principally used by sailing-vessels, and the only one for which the Coast Survey chart gives sailing directions.

North Channel, between Grassy Island and Devil's Foot Island, has about 10 feet depth for a width of 200 feet. This channel is used only by those who are familiar with the set of the currents here.

Middle Channel, in following it through from the east, is obstructed by a rock about 400 feet from the entrance with 7.9 feet on it at mean low-water. From the east end of Devil's Foot Island a reef of bowlders makes out into the channel and entirely across the channel marked out on Coast Survey chart, with 11.5 feet on its deepest part; a rock on the south end of this reef has 7.8 feet on it at mean low-water. To the south of this rock there is 20 feet depth.

The next obstruction is Middle Ledge; here the channel is about 150 feet wide, with 15 feet of water. This is a bad obstruction in the swiftest current, with deep water east and west of it. It is marked by a can buoy.

Immediately west of Middle Ledge, in the channel, is a shoal with 13.5 feet of water on it, and 20 to 27 feet all around it.

Some 1,500 feet west of the buoy on Middle Ledge there is a shoal bare at low-water; about 300 feet northeast of this are three bowlders, with 7.7 feet on them at mean low-water. The name "Entering Rocks" is given by some to the shoal, and by others to these bowlders. About 1,500 feet west of these rocks there is a rock with but 9 feet on it; it is in about 16 feet of water.

Broadway is obstructed by two or three bowlders, with less than 10 feet on them.

There is a narrow channel between Middle Ledge and Pine Island, with 14 feet of water, but this is obstructed by a cluster of bowlders with less than 1 foot on them at

low-water. If these were removed it would still be impracticable, because it is in the middle of a broad expanse of water, and could only with great difficulty be found in the night or in foggy weather.

The obstructions in the "Hole" are so great that sailing-vessels attempt its passage very rarely, and then only at or near slack-water.

A line of steamers between New Bedford and Martha's Vineyard make a trip each way daily, and in summer two trips each way, through this strait. These steamers carry freight and passengers, but their chief business is the carrying of passengers. The largest boat of this line draws 8 feet. The channel used by them has several bowlders, with less than 9 feet on them at mean low-water. These in a low run of spring tides have less than 8 feet, and on them their boats have struck repeatedly. On one occasion a boat with 600 passengers struck on one of these rocks and was disabled. All were safely landed in yawl-boats. These boats go through the "Hole" at all times of tide and in all kinds of weather.

There are four boats belonging to this line, valued at $200,000. They make about 800 trips through the "Hole" yearly, and from November 1, 1872, to November 1, 1873, carried 58,924 passengers and about 1,000 tons of freight. The officers of this company think that if the bowlders lying in the channel were removed, and a few from the point of Middle Ledge taken off, they would have but little difficulty in making the passage of this now dangerous strait. I have made an estimate for removing the few bowlders that these boats frequently strike. Besides this I have made several estimates with the view of making the use of this channel practicable by the vast coasting fleet that now passes through Vineyard Sound.

First: To remove the Entering Rocks, a few bowlders from the point of Middle Ledge, and two or three from Broadway that are serious obstructions to the navigation of the "Hole" by the New Bedford and Martha's Vineyard steamers, $5,000.

Second: To remove the bowlders as in first estimate, and all those in the channel passing Lone Rock, so as to give 200 feet in width clear of rocks, and widen the channel at Middle Ledge to 200 feet by taking the bowlders off the point of the ledge, $22,000. With this amount the channel can be much improved, and it is possible that if the bowlders are removed that the current will deepen the channel somewhat. A less amount than this will not be so economical, as the necessary apparatus for doing this work will require considerable outlay.

Third: For a channel 9 feet deep at mean low-water, and 300 feet wide at Middle Ledge, 400 feet wide at the bay entrance, and with three channels at the sound entrance, each 300 feet wide, and 9 feet deep at mean low-water, to cost—

For removing bowlders	$22,000
For dredging 18,870 cubic yards clay, gravel, and bowlders, at $1	18,870
Superintendence	2,000
Total	42,870

This improvement, by giving three wide entrances into the sound, would enable sailing-vessels to pass through from the west without danger of being drawn onto the rocks by cross-currents, because they would have a channel in any direction, and could choose the one that wind and current best suited.

Fourth: For the improvement of third estimate, and the removal of all of Middle Ledge to 9 feet at mean low-water; this would give a channel 800 feet in width, with three 300-foot channels, into the sound. With this improvement a sailing-vessel could beat through the "Hole."

For removing bowlders, second estimate	$22,000
Dredging and superintendence, third estimate	20,870
Dredging of Middle Ledge, 59,000 cubic yards, at $1	59,000
Superintendence	6,000
Total	107,870

Fifth: For a channel the same width as in fourth estimate, and 12 feet deep at mean low-water.

For removing bowlders, second estimate	$22,000
For dredging and superintendence, third estimate	20,870
For dredging and superintendence, fourth estimate	65,000
For additional dredging, 84,530 cubic yards, at $1	84,530
Superintendence	8,000
Total	200,400

Sixth: For a channel the same as in fifth estimate, with 300 feet of its width deepened to 15 feet at mean low-water, and the three entrances to the sound the same depth, (15 feet.)

For removing bowlders, second estimate	$22,000
For dredging and superintendence, third estimate	20,870
For dredging and superintendence, fourth estimate	65,000
For dredging and superintendence, fifth estimate	92,530
For additional dredging, 61,500 cubic yards, at $1	61,500
Superintendence	6,100
Total	268,000

Seventh: For a channel same as in the sixth, with 300-foot channel increased to 18 feet deep, at mean low-water.

For removing bowlders, second estimate	$22,000
For dredging and superintendence, third estimate	20,870
For dredging and superintendence, fourth estimate	65,000
For dredging and superintendence, fifth estimate	92,530
For dredging and superintendence, sixth estimate	67,600
For additional dredging, 161,500 cubic yards, at $1	161,500
Superintendence	16,500
Total	446,000

RECAPITULATION OF ESTIMATES.

First estimate	$5,000
Second estimate	22,000
Third estimate	42,870
Fourth estimate	107,870
Fifth estimate	200,400
Sixth estimate	268,000
Seventh estimate	446,000

COMMERCIAL VALUE OF THIS IMPROVEMENT.

The removal of the bowlders from the channel used by the steamers would be of great value to the steamboat company, whose boats use this channel daily; and to the thousands traveling by them, whose lives are jeopardized every time they make the passage, its value cannot be measured by dollars and cents.

The other estimates have been made with a special view to the wants of the coasting trade, and are arranged in the order that will give the most improvement for the amount expended. Each estimate is for a definite improvement complete in itself, but still a part of the plan for the greatest improvement.

The strait of Wood's Hole separates the Elizabeth Islands from the mainland, and is about twenty miles from the west end of these islands. These islands are separated from each other by Robinson's Hole and Quick's Hole, and by two or three small unnavigable ones without names, forming passages between Buzzard's Bay and Vineyard Sound. Robinson's Hole is narrow and so much obstructed by rocks that it is seldom used. Quick's Hole is a good channel, with sufficient depth, and is very much used by vessels going to and from New Bedford and other ports in Buzzard's Bay, but because of the detour around Penikese Island and a lone rock in the bay, and the comparatively short distance saved, it is but little used by the coasting-fleet passing east and west, not so much as it probably would be were it better known.

In Vineyard Sound, on the south side of the Elizabeth Islands, the tidal current sets to the eastward about four hours after it has turned and is setting to the westward in Buzzard's Bay, immediately north of them. If the channel through Wood's Hole were improved, a vessel bound west, arriving there when the tide commenced to set east in the sound, by going through the Hole, would have a fair tide four hours earlier and smooth water, and would, if depending on tide, gain much in time and distance. When a vessel bound east arrives at the light-ship off Cuttyhunk Island, and meets the tide running west out of the sound, if the wind is light she can make no headway, and must beat about the entrance until the tide changes. If, however, she could go through Wood's Hole, she would go to the north of these islands with a fair tide and smooth water four hours before she could get into the sound. Again, if this improvement were completed, two fleets of vessels arriving, one at Cuttyhunk and the other at Wood's Hole, at the same hour, would, in order to have the tide with them, one take the Buzzard's Bay route and the other the sound route, and avoid all danger of collision, if in the night or foggy weather.

The width of Vineyard Sound west of Wood's Hole, available for navigation, is made less than two miles by that dangerous shoal known as the "Middle-Ground," near the south shore. This shoal is marked only by one buoy on each end, and the uncertainty of seeing these makes all navigating the sound hug the north shore to avoid it.

They in doing this frequently get aground on the north shore in thick weather, and collisions are of frequent occurrence here.

If this improvement were made it would probably relieve this channel of nearly one-half the number of vessels now using it, and there would be the further advantage that most of those using it would be sailing in the same direction.

The number of vessels engaged in the coasting-trade is very large and annually increasing, and with this improvement made the time saved in the aggregate would be a very large item, and the lessening of the danger of accidents by collision would be, to so large a number, worthy of consideration. To vessels bound to New Bedford from the east this channel, if improved, would save ten miles in distance, and to those to Wareham nineteen miles.

Wood's Hole is in the Barnstable collection-district. The amount of revenue collected there during the fiscal year was $3,425.

Accompanying this report is a map of the survey, on a scale of 200 feet to the inch; also a chart showing the direction and velocity of the tidal flow through the Hole for an east and west tide, on the same scale as the map.

Attached to the report is a chart showing four tides in Buzzard's Bay and Vineyard Sound, plotted from the same plane.

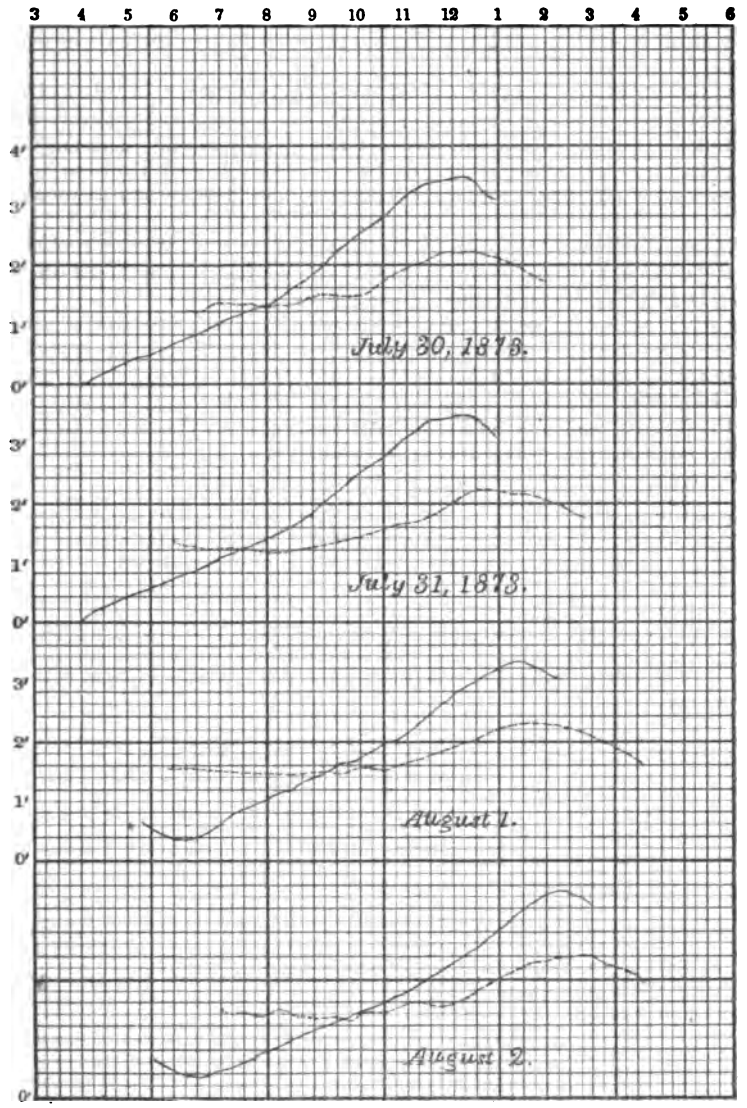
To my principal assistant, Mr. C. R. Mather, civil engineer, I am under special obligations for his valuable services in the field and office.

Respectfully submitted.

J. P. COTTON,
Assistant Engineer.

G. K. WARREN,
Major of Engineers and Bvt. Maj. Gen., U. S. A.

Tides in Vineyard Sound and Buzzard's Bay, near Wood's Hole, Mass.



Sound tide.----------
Bay tide.~~~~~

X 23.

SURVEY OF THE HARBOR OF FALL RIVER, MASSACHUSETTS.

[Report submitted December 31, 1873, and printed as part of H. Ex. Doc. 84, 43d Congress, 1st Session.]

This survey was authorized by the act of Congress approved March 3, 1873, and was, as stated in the act, made with a view to the removal of rocks from this harbor.

This survey was conducted by my assistant engineer, Mr. J. P. Cotton, and his report, with a map, is submitted herewith, to which special attention is invited for complete details of the work. The survey extends along the harbor-front about 1,500 feet, between Rodman's wharf and Brown's wharf, and out to the curve of 14 feet depth at mean low-water.

The most obvious obstructions in this space are bowlder-rocks of all sizes up to several tons' weight; but besides these the surface on which they lie is too shoal and requires dredging.

We have made an estimate for the removal of the rocks and the dredging separately, and also for a few dolphins to mark out the channel when improved and to guide and aid vessels in getting in and out.

The improved channel thus to be provided is to be 12 feet deep at mean low-water, and 100 feet wide at the narrowest parts, widening out at each end, where it joins the main channel.

The estimate is as follows:

For removing bowlders	$11,000 00
For dredging	33,400 00
For six dolphins	600 00
	45,000 00

Fall River City is a most important commercial place, and too well known to need special mention here. It is a port of entry, and the amount of revenue collected in the fiscal year ending June 30, 1873, was $212,491.42.

Very respectfully,

G. K. WARREN,
Major of Engineers, Bvt. Maj. Gen., U. S. A.

Report of Mr. J. P. Cotton, Assistant Engineer.

ENGINEER OFFICE UNITED STATES ARMY,
Newport, R. I., December 22, 1873.

GENERAL: I have the honor to submit the following report on the "survey of the harbor of Fall River, Mass., for the removal of rocks therefrom," made in accordance with your instructions:

In July I visited Fall River and conferred with the parties who had been instrumental in having this survey ordered, to learn their idea of the obstructions. From this conference and a reconnoissance I found that a survey of that part of the harbor between Rodman's wharf and Brown's wharf, and the curve of 14 feet depth at mean low-water, would include all the obstructions and would be all that was necessary to determine the improvements to be considered.

The field-work of this survey was commenced on the 6th and completed on the 13th of September. The survey extends along the harbor-front about 1,500 feet, and out to 14 feet depth at mean low-water. It was conducted in the usual manner by running a line along the shore. Important buildings and wharves were located by angles and distances. Inaccessible points were fixed by angles taken at each end of a measured base-line. The position of every station used as an instrument station that had been

fixed by triangulation was verified by repeating all of the angles of the triangle. All of the soundings were located by the intersection of lines of sight from each end of a base-line on shore, the angle that these lines made with the base being measured with a transit.

When I went to Fall River to commence the survey I expected to find an established low-water plane with a known reference to the city levels. I consulted the city engineer and the engineer of the water-works, but neither of them knew anything about the low-water plane, and the city engineer was quite sure that no observations had been made by the city. I then did what seemed best in view of the short time I should be engaged on the survey, and that was to observe the high and low waters during the progress of the work, and from those days when the tides were least disturbed by winds or storms to establish an approximate mean low-water. On three days of good weather the high-water readings were 6.0 feet, 5.9 feet, and 5.8 feet; the corresponding low waters were —1.7 feet, —1.0 foot, and —0.9 foot. Mean sea-level from these readings was 2.35 feet on the gauge, and the mean rise and fall for these three days 7.1 feet. The mean rise and fall given by the United States Coast Survey is 4.7 feet. The observations taken were at the time of spring tides, but the difference in rise and fall is too great to be charged to this alone. I have, however, assumed that mean sea-level on those days was the same as that of the United States Coast Survey, and from it have subtracted one-half the rise and fall as given by the Coast Survey for mean low-water, and to this plane have reduced the soundings.

The depth of that part of the harbor surveyed varies from 6 to 14 feet at mean low-water. The bottom, which is of gravel with bowlders and a small amount of sand, is in many places covered with bowlders varying in size from "pavers" to two tons' weight, and an occasional one of several tons. The shoalest portion, which lies in a line about west-southwest from the south side of Massasoit-Mill wharf, is known as "the ledge." The outer point of this shoal is buoyed in about 12 feet at mean low water to warn vessels passing up and down the Taunton River. To the north of this shoal there is from 8 to 14 feet of water, obstructed only by an occasional bowlder, some of them rising as much as five feet above the bottom. None of these bowlders are buoyed, and the location of but few of them is well enough known to enable them to be found readily. One opposite the Fall River Coal Company's wharf, on which several vessels have struck within the past two years, could not be pointed out with sufficient definiteness to enable me to find it without considerable search.

The removal of all the bowlders and the dredging out of the shoal would be necessary to answer fully the demands of navigation interests.

I have estimated for a channel 100 feet in width and 12 feet deep at mean low-water, to run nearly parallel with the wharves of the Massasoit Mills and Fall River Coal Company, and 50 feet from them; from the southwest corner of the Massasoit Mill wharf to curve to the southwest, and gradually increase in width until the 12-foot curve is reached, where it is to be 300 feet wide; from a point opposite the wharf of the Fall River Coal Company it is to curve to the northwest, and to be 300 feet in width where it joins the 12-foot curve. This channel properly buoyed, I think, will meet the present wants, and prevent many, if not all, of the disasters now so frequent Instead of using buoys I would put in dolphins along this channel, at intervals of about 100 feet, and on alternate sides; these would answer the double purpose of marking the channel and serving to warp to, in adverse winds.

The depth of channel estimated for is as great as could be obtained without largely increasing the estimate, and it is thought that this depth, (12 feet,) with the rise of tide (4.7) will admit any vessel likely to be engaged in coastwise trade for some time to come.

My reasons for locating the channel 50 feet from the front of the wharves are:

1st. There are often several vessels lying at a wharf waiting to discharge; if the channel was immediately in front of the wharves it would, in such a case, be partially blocked, and questions as to the right of way would be constantly arising.

2d. The foundation of some of the wharves is on the present bottom; should the depth alongside be increased there would be danger of undermining and throwing them down.

There is now in a large part of the proposed channel 12 feet of water at mean low-water, where all that is required is the removal of the scattering bowlders. It is thought that most of these bowlders can be weighed with proper apparatus. There was but one found that will require to be blasted. The cost of removing these bowlders it is difficult to estimate. In sounding, only a small number of those that will have to be removed were found, and the sizes of only the larger ones of those found were estimated. If the improvement is made the proposed channel should be buoyed, and all the bowlders within its limits taken up. This could be done only with the aid of divers. I estimate the cost of removing the bowlders from the proposed channel at $10,000.

The dredging of the channel to 12 feet depth at mean low-water will require the removal of 30,400 cubic yards. Dredging at the wharves in Fall River costs about $1 per cubic yard, and I think this can be done at that price.

ESTIMATES.

Removing bowlders	$10,000	
Superintendence	1,000	
		$11,000
Dredging 30,400 cubic yards at $1	30,400	
Superintendence	3,000	
		33,400
Six dolphins		600
		45,000

I have collected the following data concerning the amount of merchandise received and shipped during the year ending November 1, 1873, at the wharves in that part of the harbor of Fall River included in this survey:

Coal, tons.	Grain, bushels.	Bricks.	Lime and cement, bbls.	Lumber, f't, b. m.
119,800	460,000	350,000	9,000	8,201,546

Value of merchandise carried by Providence steam-packet, $5,000,000; number of arrivals and departures exclusive of the steam-packet, about 700; number that have struck on the obstructions, 45. Of this number about one-half received serious damage. One loaded with lime ran on a rock at high-water, and when the tide fell she keeled over and filled; the lime caught fire and the vessel and cargo were nearly a total loss. So many vessels have struck during the past two years that it is difficult to charter vessels to bring coal here.

Fall River Harbor possesses extra facilities for navigation. It is a part of Mount Hope Bay, an arm of Narragansett Bay, and is seldom obstructed. The bay is wide, so that vessels can beat up to town.

Fall River in 1870 had about 27,000 inhabitants, and is increasing in population very rapidly. It now ranks first in the United States in the extent of its cotton manufacturing interest. It is a port of entry. The amount of revenue collected during the fiscal year ended June 30, 1873, was $212,491.42.

Accompanying this report is a map on a scale of 100 feet to 1 inch, of that part of the harbor surveyed, with the wharves north and south in dotted lines, taken from the city map.

Mean low-water, to which the soundings on this map were reduced, is — feet below the top of ring-bolt in the cap of Slade's wharf, about 60 feet from the northwest corner, on the north side.

I was assisted in this survey by Messrs. Clarence L. Howes and Wm. F. Hill, civil engineers.

Respectfully submitted.

J. P. COTTON,
Assistant Engineer.

G. K. WARREN,
Major of Engineers and Brt. Maj. Gen., U. S. A.

X 24.

SURVEY OF POINT JUDITH LAKE, [POND,] RHODE ISLAND.

[Report submitted December 31, 1873, and printed as part of House Ex. Doc. 84, 43d Congress, 1st session.]

This survey was made in accordance with the act of Congress for rivers and harbors approved March 3, 1873.

This survey was specially conducted by my assistant engineer, Mr. C. R. Mather, and his report in detail, and a map on a scale of 200 feet to the inch, are sent herewith.

This lake, usually called pond, is one of several formed by a sand-beach thrown by the waves between Point Judith and highland lying

west of it. It is about 3,000 feet average width, and 20,000 feet long, receiving the drainage of an area of about twenty-five square miles. The level of the pond at the time of the survey was about 4½ feet above mean low-water in the ocean. The water in the pond is mostly fresh, and escapes at nearly all times of tide through a narrow crooked outlet through the beach near the western side of the pond. At very high tides and high waves salt water finds its way into the pond through the outlet and over the low ground contiguous to it. This opening, I believe, is never entirely closed by the beach-sand, though it has narrowed so much that large fish do not enter it as numerously as in former times. There is probably no danger of its ever closing, as the head of water and the area drained are sufficient to always find an outlet.

From the 6-foot curve in the ocean to where the pond is 6 feet deep is a distance of 7,500 feet, and if a canal and lock were practicable, this would be the length of the canal required to give 6 feet depth. If it were practicable to establish a permanent outlet, so as to allow the tide to enter the pond freely and preserve its mean level the same as the ocean, the pond would be lowered 4½ feet, and the distance from the curve of 6 feet depth in the ocean to the same depth in the pond would become 8,000 feet, and this would represent the length of the canal to be cut. This latter arrangement would render the pond valuable for raising oysters, and for such fish as prefer salt-water estuaries, but the fresh-water pond is probably more valuable for the herring fishery.

To secure any artificial enlargement of the outlet extensive stone jetties would be required on each side, to prevent the opening being filled with the sand, and even these, unless of very great extent, would be of doubtful effect, for the beach is composed of shifting sand, exposed to the full force of the ocean waves.

The village of Wakefield is situated at the head of this pond, and if vessels of moderate draught could be made to reach it, the people would be much benefited; but the cost of making suitable works to effect this would be so great, that nothing but the commerce of a great city like New York would justify the attempt. There an artificial harbor costing millions could be afforded, and only under its shelter could the beach be kept permanently open. I therefore submit no estimate for improvement.

Very respectfully,

G. K. WARREN,
Major of Engineers, Bvt. Maj. Gen., U. S. A.

Report of Mr. Charles R. Mather, Assistant Engineer.

ENGINEER OFFICE, UNITED STATES ARMY,
Newport, R. I., December 19, 1873.

SIR: I have the honor to submit herewith a report upon a survey and examination of the southern portion and outlet of Point Judith Pond, Rhode Island, together with suggestions for establishing navigable communication with the pond and ocean.

In accordance with your instructions I repaired with the party in my charge to Point Judith Pond on August 2, 1873, and commenced the survey of the pond and outlet on August 4, 1873, completing it on the 27th of that same month.

Before describing the survey proper I will endeavor to give an outline of the position and extent of the pond, together with some description of its feeders and water-shed.

The Point Judith Pond lies in a comparatively large basin, being bounded on the east by that crest of hills running northward along the west shore of Narragansett Bay, and turning inland near Narragansett Pier, and bounded on the west side by that slope of country running to the westward which forms the east side of the water-shed of the Pawcatuck River, and the numerous ponds located on the southern shore of Rhode Island.

The southern limit of the pond commences at a distance of some 2,000 to 4,000 feet from the ocean, and extends northward about four miles, to within one-half of a mile of the village of Wakefield. It here narrows practically to a brook, known as the Saugatucset River, which extends northward some five miles, having for feeders two small branches named Indian River and Rocky Brook.

The Saugatucset and branches drain that portion of the country lying some five miles back of Narragansett Bay, and immediately north of Narragansett Pier, while the Pettaquamscott River, emptying in the ocean near Narragansett Pier, does the same for the bay slope.

The pond itself is quite irregular in its conformation of shore-line, and is interspersed with numerous islands, varying very much in size. The length of the pond is about four miles, the maximum breadth one mile. The southern limit of the pond is a large marsh, interspersed with various creeks. This marsh bounds the entire southern portion of the pond, and is itself limited by a range of sand-hills, of some 25 feet in height, fronting on the ocean beach. At the western limits of these hills the present "breach" or opening is.

This is a shallow outlet, of nearly constant width of 200 feet, and general depth of 1½ feet.

A prominent feature of the pond is Great Island, lying some 1,200 feet north of the marsh, and almost, if not entirely, dividing the pond into two distinct portions for a distance north of quite a mile.

The marsh also may be considered an important feature of the pond, in so far as it pertains to the future regimen of the same. From the information gained while on the ground, I should judge that the northern limit of the marsh was gradually encroaching on the limits of the pond, and that a subsidence of the matters in suspension is constantly going on, which has and is increased proportionally to the diminished circulation, caused by the gradual and increasing closing of the "breach."

The changes that have taken place in the pond during the past seventy years are very marked. Previous to 1815 the outlet of the pond to the ocean was on the east side of the pond. This outlet was closed by the "great gale" in September of that same year, and no traces now exist to point out that there ever was an outlet there, except the stony character of the beach near the old outlet. The present breach is about one mile west of the former opening, and its shores, being entirely of sand, are unstable and shifting.

The survey extended along the ocean-beach south of the pond and eastward of the same to within 1,000 or 1,500 feet of Point Judith light-house. The western limit of the survey is some 700 or 800 feet west of the present breach or outlet of the pond, which is beyond the western limit of the pond proper. It extends north (up the pond) to a point locally known as Beef Island. The entire survey constitutes an area nearly approximating in form to that of a square whose sides are about 11,000 feet in length.

The method of conducting the survey consisted in first covering the marsh to the south of the pond, and also the ocean-beach, with lines of traverse, closing on an arbitrary starting-point, and forming a polygon of some twenty-three sides, the angular correctness of which was determined by a comparison of the difference of the right and left deflections with 360°. The linear measurements were tested by calculations of the latitudes and departure of the traverse lines and comparisons of the sums of the same. The linear measurements were also tested by platting. To prevent any gradual accumulation of small and uncertain errors, the eastern portion of the polygon was subdivided into a smaller one, and its correctness determined as before. Upon the accuracy of this latter polygon the position of all the stations on the upper portions of the pond depended.

The shores of the pond, together with the northern limit of the marshes, were located entirely by triangulation, it being considered that this would be economical of time, being, in fact, the only practicable way to locate the outlines of the marsh and the numerous creeks therein.

Stations for doing this were located on the east and west shores of the pond, and on the same shores of Great Island, by a system of triangulation connecting with a side of the smaller polygon just previously mentioned.

A tide-gauge was established in the pond, which developed the fact that practically there was no oscillation of tide going on in the pond, the maximum difference of readings on the gauge being 0.3 of a foot. A buoy-gauge was also placed in the ocean and read for three consecutive days, and the height of mean low-water established by subtracting one-half of the mean rise and fall of the tides, as given by the United States Coast Survey, from the mean sea-level determined from the readings. The two gauges were connected by lines of level, and the difference of height of the zeroes of the gauges compared. This comparison showed mean low-water in the ocean to be 4.5 feet below the surface of the pond at the time of this survey.

Soundings were taken inside the pond, on both sides of Great Island, as far north as gave 9 feet and over in the west passage of the pond, 6 feet being the limit of depth

obtained on the east side of Great Island. This latter depth was about the maximum to be obtained in the east passage. In the ocean, from Point Judith west to within 2,500 feet of the present breach, soundings were taken from the shore to a depth of over 25 feet. The soundings were located by the intersection of known lines of sight from two transits.

The wishes of the people consulted in the matter, relative to the desired improvement, seem to universally be that the pond should be connected with the ocean in such a manner that vessels drawing from 7 to 8 feet may pass into the pond. The object of the improvement is, however, twofold:

First. To give communication by water to that section of country lying near the head of the pond, which contains quite a number of moderately-sized manufacturing villages, or, in other words, to give that section an opportunity to get their supplies and send off their exports direct by water. This section of country now brings a large portion of the former to Providence, and re-transports them by rail via the Providence and Stonington Railroad to the station on that road nearest to the ultimate destination, from which station they are brought by teams, for varying distances, to the desired place. This increase of transportation and consequent expense would be almost entirely obviated if the pond were connected with the ocean in the manner spoken of in the preceding paragraph.

Second. To meet the wishes of the fishing interest, as during the winter months, more especially in former years, enormous quantities of bass and perch entered the pond during this season of the year, and the catching of these fish gives employment to numbers of men living near the pond. I have been informed that large quantities of oysters were formerly obtained in the pond, but have now almost entirely disappeared, owing to the impeded circulation in the pond caused by the gradual closing of the breach. I could not obtain any extended information as to what might be the average magnitude of these fishing interests, but have been informed that it reaches the sum of $20,000 per season.

The plan for making a navigable connection with the ocean best adapted to the case is the construction of a canal and lock connecting the pond with the ocean. This method of connection may be considered almost necessary on account of the difference of level between the pond and ocean. This would satisfy the requirements of the first object of the improvement, and, if the second should be considered of sufficient importance to warrant an expenditure, the present breach might be dredged and opened at the mouth to permit the more easy access of fish to the pond.

For the choice of location of the canal there offer two places. One line lies on the eastern side of the pond, and presents in its favor the fact that the ground is quite level for a distance of at least one-half of its length; for the remaining distance there is a gradual rise to the summit of the beach. The hard and stony character of the beach here is also in favor of this location. This hardness may be of sufficient character and depth to do away almost or entirely with artificial means to preserve the mouth of the canal from filling up.

The other choice for a line of canal is the present opening or breach. The only thing to be said in favor of this location is the level character of the surrounding marsh near it, extending to the mouth of the breach. The breach-creek itself is too crooked to be made use of as a canal by excavation and dredging, and offers the further objection of the extremely unstable and shifting character of its mouth. This unstableness would necessitate the construction of expensive jetties on probably both sides of the opening of the proposed canal, as well as causing the building of them some distance inland to prevent the possibility of the sea ever breaking over the beach and sand-hills near the opening.

If the fishing interests were alone consulted in the proposed improvement, the present breach might be utilized, by dredging, to assist the wants of this interest. If this were done it would still be necessary to protect the mouth of the breach by jetties, and it is quite questionable if the opening could be successfully secured against the strong probability of storms closing it during the prosecution of the work.

Accompanying this report is a map of that portion of the pond and ocean within the limits of the survey, on a scale of 200 feet to the inch. This map is illustrated with sections of level taken at characteristic portions of the beach, sand-hills, and marsh, on a scale of 100 feet to the inch horizontal and 10 feet vertical distances.

I was assisted with commendable energy and earnestness during the entire survey by Mr. C. L. Howes, civil engineer, Mr. Edward Higginson, and Mr. W. P. Chrystie.

Very respectfully,

CHARLES R. MATHER,
Assistant Engineer.

G. K. WARREN,
Major of Engineers and Bvt. Maj. Gen., U. S. A.

APPENDIX Y.

ANNUAL REPORT OF LIEUTENANT-COLONEL GEORGE THOM, CORPS OF ENGINEERS, FOR THE FISCAL YEAR ENDING JUNE 30, 1874.

UNITED STATES ENGINEER OFFICE,
Portland, Me., August 17, 1874.

GENERAL: I have the honor to submit herewith my annual reports upon works of river and harbor improvements, and of examinations and surveys under my charge, for the fiscal year ending June 30, 1874.

Very respectfully, your obedient servant,

GEO. THOM,
Lieut. Col. of Engineers, Bvt. Brig. Gen., U. S. A.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

Y 1.

IMPROVEMENT OF ST. CROIX RIVER, ABOVE THE "LEDGE," MAINE.

The following appropriations have been made for the improvement of this river:

By act of Congress approved March 2, 1867	$15,000 00
By act of Congress approved March 3, 1873	10,000 00
By act of Congress approved June 23, 1874	10,000 00
Total	35,000 00

The act of March 2, 1867, contained a proviso that—

The province of New Brunswick contribute and pay to the proper disbursing officer a like sum for said purpose; said payment being made on condition that in no event shall the province of New Brunswick be called upon for more than half the sum actually expended for said purpose.

In July, 1873, information was received by the Department from the minister of public works of the Dominion of Canada, that $25,000 had been appropriated by Parliament—

For the removal of slabs, sawdust, and other obstructions in the St. Croix River, which runs between the province of New Brunswick and the State of Maine.

It being understood that the Government of the United States had appropriated a certain sum for the same purpose, it was suggested—

Whether the two governments might not act jointly in the matter.

By an arrangement made between the United States Secretary of War and the minister of public works, (as will appear in the accompanying correspondence, marked A, 1, 2, 3, 4, 5,) this work was intrusted to Henry F. Perley, esq., engineer, department of public works, and myself.

With a view to deciding upon a definite plan for the improvement of this river, in such a manner as would meet the approval of both governments, an accurate survey was made under my direction in July, August, and September, 1873, of that portion of it which is embraced be-

tween "the Ledge" and the bridge connecting Calais, Me., with St. Stephen, N. B., a distance of about five miles, the expenses of which survey have since been equally shared by the two governments. A project for the improvement of this river was prepared by Mr. Perley and myself, in November last, the drawing explanatory of which was forwarded to the Department in March last. With a view to preparing a project for this work under the additional appropriation of $10,000, made by act of June 23, 1874, I addressed a communication to Mr. Perley to ascertain what action, if any, had been taken by his own government in this matter; in reply to which (see accompanying copies of the correspondence marked B, 1, 2, 3) I was informed that the minister of public works would not consent to the expenditure of any portion of the sum of $25,000, which had already been voted by that government for this work, until thoroughly satisfied that there would be no further deposition of slabs and sawdust from the mills on the St. Croix; arguing that if the river were cleared out as proposed there is now no guarantee that the river would remain in a state of efficiency, but would soon be closed up again and require further expenditure.

These views entirely coincide with my own, as communicated in my report to the Department dated September 10, 1867; and the attention of Congress was then asked to the matter, with a view to such legislation as might be necessary to prevent the future obstruction of this and other rivers. No attention, however, appears to have been given to the matter, so that there does not now exist any law or authority sufficiently strong for effecting the desired object. Under all the circumstances above stated, it is not probable that any further work will be undertaken at present for the improvement of this river. The attention of Congress is again respectfully asked to this matter, and to the necessity for some general law to protect from injury and obstruction all navigable waters under the control of the United States, and for the improvement of which Congress has already made or may hereafter see fit to make appropriations.

This river throughout its whole extent forms a part of the international boundary; and that portion of it for which improvements are projected lies within the collection-district of Passamaquoddy, the nearest port of entry being Calais, Me.

The light-house nearest thereto is on Dochet's Island, in St. Croix River, about eight miles below Calais; and the nearest fort is Fort Sullivan, at Eastport, Me., about thirty miles below Calais.

The amount of duties collected at the port of Calais for the fiscal year ending June 30, 1874, and the extent to which commerce and navigation would be benefited on the part of the United States by the contemplated improvement of this river, are exhibited in the appended statement marked C, courteously furnished by the deputy collector at that port.

Financial statement.

Balance in Treasury of United States July 1, 1873	$24,000 00
Amount in hands of officer and subject to his check, (including percentage due on contracts not yet completed)	983 25
Amount appropriated by act approved June 23, 1874	10,000 00
Amount expended during the fiscal year ending June 30, 1874	797 67
Amount available July 1, 1874	34,185 58

Correspondence relative to proposed improvement.

A 1.

OTTAWA, *July* 14, 1873.

SIR: I am directed by the minister of public works to state that a sum of $25,000 has been appropriated by the Parliament of the Dominion for the removal of slabs, saw-

dust, and other obstructions in the St. Croix River, which runs between the province of New Brunswick and the State of Maine, and that it is understood that the Government of the United States have appropriated a certain sum for the same purpose.

I am, therefore, to request you will be pleased to inform me of the amount of the said appropriation, the nature and extent of the work to be executed, and whether the two Governments might not act jointly in the matter.

I have the honor to be, sir, your obedient servant,

F. BRAUN,
Secretary.

The SECRETARY OF WAR,
Washington, U. S. A.

A 2.

OFFICE OF THE CHIEF OF ENGINEERS,
Washington, D. C., July 21, 1873.

SIR: The letter of the secretary of the department of public works of Canada, of the 14th instant, in reference to the improvement of the St. Croix River, Maine, and stating that an appropriation has been made therefor by the Canadian government, is herewith respectfully returned.

The act making appropriations for the repairs, &c., of certain public works, &c., approved March 2, 1867, contains the following item: "For the purpose of improving the navigation of the St. Croix River, Maine, above the ledge, fifteen thousand dollars: *Provided*, The province of New Brunswick shall contribute and pay to the proper disbursing officer a like sum for said purpose. Said payment being made on condition that in no event shall the province of New Brunswick be called upon for more than half the sum actually expended for said purpose." The co-operation of the province not having been obtained, the work of improvement was not commenced.

The officer in whose district the St. Croix River lies, Colonel Thom, in his annual report to this office dated September 14, 1872, states that for an accurate estimate of the amount that is required for entire and permanent completion of the improvement, a careful survey would be necessary. He estimated that it would require the removal of not less than 100,000 cubic yards of slabs, edgings, and sawdust to make a channel 100 feet wide and 10 feet deep at low-water, at a cost of about $100,000, one-half to be paid by the province of New Brunswick.

The act making appropriations for the repair, preservation, and completion of certain public works, &c., approved March 3, 1873, has an item "for the improvement of the St. Croix River, above the ledge, Maine, $10,000." This appropriation contains no proviso, and will be expended by the officer of engineers having charge, (Lieutenant-Colonel Thom,) as soon as an accurate survey can be made of the river from the "ledge" to Calais, the head of navigation.

This survey, it is expected, will be made during the present month, at a cost of about $1,000.

The amount then available of the appropriation of March 2, 1867, including the $1,000 above referred to, is	$15,000
Appropriated March 3, 1873	10,000
Total available	25,000

which is the amount appropriated by the Dominion of Canada.

It is respectfully recommended that the department of public works of Canada be requested to confer with Lieut. Col. George Thom, Corps of Engineers, at Portland, Me., in regard to the expenditure of the appropriation made by the Dominion of Canada, and that Colonel Thom be authorized to make such arrangements with the Canadian authorities, subject to the approval of the War Department, as will best subserve the interests of both parties.

By command of Brigadier-General Humphreys, and in his absence.

Very respectfully, your obedient servant,

J. G. FOSTER,
Lieut. Col. of Engineers, Bvt. Maj. Gen., U. S. A.

Hon. W. W. BELKNAP,
Secretary of War.

Approved.
By order of Secretary of War.

W. T. BARNARD,
Acting Chief Clerk.

JULY 23, 1873.

A 3.

WAR DEPARTMENT,
Washington, D. C., July 26, 1873.

SIR: In reply to your letter of the 14th instant, requesting to be informed of the amount appropriated by the United States Government for the removal of slabs, sawdust, and other obstructions in the St. Croix River, the nature and extent of the work to be executed, and whether this Government could not act jointly in the matter with the Dominion government, I have the honor, in the absence of the Secretary of War, and by his direction, to invite your attention to the inclosed copy of the Report of the Chief of Engineers upon the subject, dated the 21st instant, with request that the department of public works of Canada confer with Lieut. Col. George Thom, Corps of Engineers, Portland, Me., in regard to the expenditure of the appropriation referred to in your letter; Colonel Thom having been authorized to make such arrangements, subject to the approval of this Department, as will best subserve the interests of both governments.

Very respectfully, your obedient servant,

W. T. BARNARD,
Acting Chief Clerk.

SECRETARY DEPARTMENT OF PUBLIC WORKS,
Ottawa, Canada.

A 4.

OFFICE OF THE CHIEF OF ENGINEERS,
Washington, D. C., August 2, 1873.

SIR: The inclosed copy of a communication from the minister of public works of the Dominion of Canada to the Secretary of War upon the subject of the improvement of the navigation of the St. Croix River, with copies of letters from this office to the Secretary of War and the reply to the Canadian authority, are forwarded to you for your information.

You will perceive the department of public works has been requested to correspond with you in regard to the expenditure of the appropriation made by the Canadian Parliament, and you are authorized to make such arrangements, subject to the approval of this office, as will best subserve the interests of both governments.

By command of Brigadier-General Humphreys.

Very respectfully, your obedient servant,

JNO. G. PARKE,
Major of Engineers.

Lieut. Col. GEORGE THOM,
Corps of Engineers.

A 5.

ST. JOHN, N. B., *September* 8, 1873.

SIR: I am instructed by the honorable the minister of public works of the Dominion of Canada to place myself in communication with you, relative to the joint expenditure of sums voted by the Government of the United States and that of the Dominion, for the purpose of improving the navigable channel of the St. Croix River.

For the purpose of consulting with you respecting this work, I purpose calling on you on Monday morning next, the 15th instant.

If this suits your convenience, will you be kind enough to telegraph me to that effect, and also your address.

I have the honor to be, sir, your obedient servant,

HENRY F. PERLEY,
Assistant Engineer, Depart. Public Works.

Lieut. Col. THOM,
Corps of Engineers, U. S. A., Portland, Me., U. S.

B 1.

UNITED STATES ENGINEER OFFICE,
Portland, Me., July 4, 1874.

DEAR SIR: I have just been advised that an additional appropriation of $10,000 has been made for improving the navigation of St. Croix River, making altogether $35,000

appropriated by the United States Government for that work. Will you do me the favor to inform me what action, if any, your own government has taken in this matter, and if there is any probability that you will be able to do anything this season?

Very truly yours, &c.,

GEO. THOM,
Lieut. Col. of Engineers, Bvt. Brig. Gen.; U. S. A.

HENRY F. PERLEY, Esq.,
Assistant Engineer, Department of Public Works, St. John, N. B.

B 2.

ST. JOHN, N. B., *July* 13, 1874.

DEAR SIR: Absence from St. John is the reason why I have not replied to yours of the 4th instant before.

The sum of $25,000 was re-voted at the last session of Parliament for the improvement of the St. Croix River, but the honorable the minister of public works states that he will not consent to the expenditure of any portion of that amount until he is thoroughly satisfied that there would be no further deposition of slabs and sawdust from the mills on the St. Croix, arguing that if the river was cleared out as proposed by your plan there is now no guarantee that the river would remain in a state of efficiency, but would soon be closed up again, and require further expenditure.

Yours, faithfully,

HENRY F. PERLEY.

Bvt. Brig. Gen. THOM,
U. S. Engineer, Portland, Me.

B 3.

UNITED STATES ENGINEER OFFICE,
Portland, Me., July 15, 1874.

DEAR SIR: I have to acknowledge the receipt of your letter of the 13th instant, informing me, in reply to mine of 4th instant, that the sum of $25,000 was re-voted at the last session of Parliament for the improvement of St. Croix River, but that the honorable the minister of public works states that he will not consent to the expenditure of any portion of that amount until he is thoroughly satisfied that there would be no further deposition of slabs and sawdust from the mills on the St. Croix, arguing that if the river was cleared out as proposed there is now no guarantee that the river would remain in a state of efficiency, but would soon be closed up again, and require further expenditure.

In my first report to the Chief of Engineers on the improvement of this river, dated September 10, 1867, I stated that "while the causes of these obstructions to navigation continue in operation, [to wit, throwing of slabs, edgings, and sawdust into the river from the numerous saw-mills on both its banks, above and near Calais, Me., and St. Stephen, New Brunswick,] it would not appear to be advisable to expend the appropriation, viz, $15,000, made by act of March 2, 1867, in removing them until a sufficient protection should be given to the channel by adequate State laws, or else by such laws of Congress as might be necessary to prevent obstructions or other injury to its navigable waters. To this matter the attention of Congress was asked at as early a day as practicable, but as yet no action thereon has been taken.

Now, any control over the navigation of this river, forming as it does a part of the international boundary, must necessarily be derived either from a treaty or else from joint legislation on the part of the State of Maine and the Dominion of Canada, by which commissioners may be empowered to prevent any further injury thereto whatever. At present there does not appear to be any law or authority sufficiently strong for effecting this object, so that it is not probable that any further steps will be taken at this time by either government for the improvement of this river under the appropriations made therefor, more especially as the act of Congress, approved March 2, 1867, making the first appropriation for this work, provides that "the province of New Brunswick shall contribute and pay to the proper disbursing officer a like sum for said purpose, said payment being made on condition that in no event shall the province of New Brunswick be called upon for more than half the sum actually expended for said purpose."

Very respectfully, your obedient servant,

GEO. THOM,
Lieut. Col. of Engineers, Bvt. Brig. Gen., U. S. A.

HENRY F. PERLEY, Esq.,
Assistant Engineer, Department of Public Works, Dominion of Canada, St. John, N. B.

C.

Commercial statistics.

CUSTOM-HOUSE,
Calais, Me., July 31, 1874.

Statement showing amount of revenue collected at this port during fiscal year ending June 30, 1874; also other statistics relating to the business of this port during the same period.

Revenue collected	$31,000 00
Domestic exports.	
Long lumber, superficial feet	82,000,000
Laths	68,000,000
Shingles	38,000,000
Pickets	868,000
Spool-stuff	246,000
Posts and railroad-ties	55,000
Clapboards	50,000
Ship-knees	68,000
Hoops	200,000
Calcined plaster, barrels	40,000
Sand-plaster, casks	12,000
Foreign exports.	
Long lumber, superficial feet	2,500,000
Foreign imports.	
Rock-plaster, tons	8,144
Domestic imports.	
Flour, barrels	28,000
Corn, bushels	128,000
Pork and beef, barrels	3,500
Coal, tons	3,100
Lime, casks	6,530
Arrivals of vessels.	
Domestic	1,029
Foreign	70
Clearances of vessels.	
Domestic	1,004
Foreign	87
Vessels built.	
Sixteen schooners, total tonnage	2,635
Vessels rebuilt.	
Four schooners, total tonnage	474

Repaired at dry-dock and railways.

One hundred and eighty vessels.

River open for navigation 300 days.

W. M. HAYCOCK,
Deputy Collector and Inspector.

Y 2.

IMPROVEMENT OF MACHIAS RIVER, MAINE.

The following appropriations have been made for the improvement of this river, viz:

By act of Congress approved March 3, 1873	$12,000 00
By act of Congress approved June 23, 1874	10,000 00
Total	22,000 00

With a view to improving the navigation of this river, a survey of it was made in 1872, showing that it was formerly navigable at *mean low-water*, from its mouth at Machiasport up for a distance of five miles to the falls of Machias for vessels of 6-foot draught, the average rise and fall of the tides being 13.3 feet; that there is a good, unobstructed channel, with 18 feet of water, at mean low-water, as far up as the mouth of East Machias River, (being about four miles below the falls at Machias;) and thence up one mile to the draw-bridge between Machiasport and East Machias, a good 12-foot channel. Above the draw-bridge for a distance of about two miles (being to a point about one mile below the falls) the channel has not less than 6 feet of water at mean low-water for a width, except in one locality, of not less than 150 feet. Above that point the channel becomes narrow and tortuous, not having a greater depth than 3 feet at mean low-water, owing to the obstructions (known as the "middle ground") caused chiefly by the waste from the saw-mills at and above the falls.

In order to so improve the navigation of this river as to meet the requirements of its commerce, it is recommended that its channel be so enlarged as to have a depth of 6 feet at mean low-water for a width of 150 feet, all the way up to the wharves at Machias. To effect this would require the removal of the following obstructions, viz:

1. *Shoal near draw-bridge.*—This consists mostly of mud and saw-dust, intermixed with a few logs and slabs, and requires the excavation of 1,300 cubic yards, the estimated cost of which, at 50 cents		$650 00
2. *Shoal or narrows off Libby Head.*—This consists of mud and saw-dust, 5,100 cubic yards at 50 cents		2,550 00
3. *The "middle ground."*—This consists of about 42,300 cubic yards of mud and saw-dust, the estimated cost of removing which, at 50 cents	$21,150 00	
and 14,000 cubic yards of slabs and edgings, at 60 cents	8,400 00	
		29,550 00
4. *Middle Rock.*—To remove this to a depth of one foot below the plane of mean low-water would require 1,553 cubic yards of excavation, which, at $6.75 per cubic yard, (the price contracted for,) would amount to		10,482 75
adding for engineering expenses and other contingencies, say		4,767 25
Total		48,000 00
Amount appropriated by acts of March 3, 1873, and June 23, 1874, as above		22,000 00
Additional amount required for completing this work		26,000 00

On the 23d of June, 1873, a contract was made with Mr. Edouard M. Le Prohon, of Portland, Me., for the removal of Middle Rock, at $6.75 per cubic yard, under the appropriation of March 3, 1873. On the 14th of July he commenced work, and continued it with energy up to the 10th of November, 1873, when, on account of the high stage of the river, he was obliged to suspend operations until spring. About the 1st of June, 1874, operations were resumed for a few days, but owing to the high and unfavorable condition of the river they were again suspended until about the 1st of July.*

After having completed the removal of Middle Rock, in Machias Harbor, which is by far the most important improvement of this river, the work that will then remain to be done consists in the excavation of about 63,000 cubic yards of slabs, edgings, saw-dust, &c., from the channel between Machias Village and the draw-bridge. For this work there will be an available balance of about $11,500 of the appropriations hitherto made, which is to be applied to the deepening of the channel

* On the 28th of July, 1874, this work was completed down to an average depth of about one-half a foot below the plane of mean low-water.

at the "middle ground," where obstructed by slabs, edgings, and saw-dust thrown in from the mills above.*

The benefit to be derived from this expenditure, or from any future appropriation for the work, will be but temporary, unless Congress shall, by suitable legislation, protect this river from injury and obstruction hereafter in the same manner as recommended for the St. Croix and Penobscot Rivers.

Financial statement.

Balance in Treasury of United States July 1, 1873	$11,000 00
Amount in hands of officer and subject to his check	950 84
Amount appropriated by act approved June 23, 1874	10,000 00
Amount expended during the fiscal year ending June 30, 1874	5,504 44
Amount available July 1, 1874	14,758 90
Amount required for the fiscal year ending June 30, 1876	26,000 00

Y 3.

IMPROVEMENT OF NARRAGUAGUS RIVER, MAINE.

The navigation of this river from its mouth in Millbridge up to the head of navigation at the bridge in Cherryfield, a distance of about seven miles, has hitherto been much obstructed by numerous ledges, bars formed of slabs, edgings, and saw-dust, and a very large number of sunken bowlders.

For the improvement of this river the following appropriations have been made, viz:

By act of Congress approved March 3, 1871	$12,000 00
By act of Congress approved June 10, 1872	10,000 00
Total	22,000 00
Of this amount there was unexpended on the 1st of July, 1873	$4,763 89

Up to this period about 4,900 tons of ledge and bowlders and 2,000 cubic yards of slabs and edgings had been removed from the channel and bed of the river.

These operations were continued from the 1st of July, 1873, until the middle of October, during which time the following additional work has been done, viz:

535 tons of sunken ledge and bowlders removed from the falls and in its vicinity below;
500 tons of sunken ledge and bowlders removed from Freeman's Point and its vicinity;
300 tons of sunken ledge and bowlders, removed between Freeman's Point and the bridge at Cherryfield;
3,400 cubic yards of slabs, edgings, and saw-dust removed below Freeman's Point;
1,600 cubic yards of slabs, edgings, and saw-dust removed between Freeman's Point and the bridge;

Making a total to date of over 3,000 cubic yards of sunken ledges and bowlders, and 7,000 cubic yards of slabs, edgings, and saw-dust which have been removed from the channel and bed of the river; all which has been done with hired labor.

In addition to this work a large wrought-iron (9-inch) spindle, with day-mark, has been placed upon Half-Tide Rock, at Millbridge. Two

* On the 15th of August, 1874, invited proposals were opened for this work, and a contract therefor was awarded to Messrs. Curtis, Fobes & Co., of Portland, Me., for 18,000 cubic yards of dredging, (they being the lowest of two bidders,) at 60 cents per cubic yard.

spar-buoys have also been placed on the ledges on each side of the narrow channel near Small's Point, and two more on the ledges below "the falls."

This completes all the work that has been projected for the improvement of this river, whereby the appropriations made therefor have been totally exhausted.

By this work the navigation of this river has been greatly improved in its safety and depth of channel; so much so, that coasting vessels of light-draught, with center-boards, have of late, for the first time, been running to and from the wharves at Cherryfield, taking out lumber and other products of the country, and returning with coal and general merchandise, without transshipment, as formerly, at Millbridge.

Financial statement.

Balance in Treasury of United States July 1, 1873	$3,000 00
Amount in hands of officer and subject to his check	1,763 89
Amount expended during the fiscal year ending June 30, 1874	4,763 89

Y 4.

IMPROVEMENT OF SULLIVAN RIVER AND SULLIVAN FALLS, MAINE.

This river is navigable from its mouth up to Franklin, a distance of about nine and a half miles. Hitherto it has been seriously obstructed and its navigation endangered by Hatcher's Rock and numerous other sunken ledges in "the falls," and by the stone foundations of several bridge-piers one mile above "the falls."

For the improvement of this river and "the falls," the following appropriations have been made by Congress, viz:

By act of March 3, 1871	$10,000
By act of June 10, 1872	25,000
Total	35,000

Under the appropriation of March 3, 1871, a contract was made May 8, 1871, with Mr. George W. Townsend, of Boston, Mass., the lowest bidder, at $35 per cubic yard, for removing 270 cubic yards of Hatcher's Rock. This work was completed on the 1st of August, 1871, by which an increased depth of 4 feet was obtained over the rock, giving 3½ feet at mean low-water, or 11½ feet at mean high-water.

Under the appropriation of June 10, 1872, a contract was made August 26, 1872, with the same party, who was the only bidder, for the following work, viz:

1. Removing two or more bridge-piers, to a depth of 10 feet below mean low-water, at (each pier)	$3,000
2. Blasting out Hatcher's Rock, to a depth of 7 feet at mean low-water, 147 cubic yards, at $35	5,145
3. Blasting out to same depth the Point of Ledge near Hatcher's Rock, 24 cubic yards, at $35	840

Up to the 1st of July, 1873, the following work had been done under this contract, viz:

Three bridge-piers (Nos. 4, 5, and 6, counting from the northern or Sullivan shore) removed to a depth of 10 feet below mean low-water, and the partial breaking up of the Point of Ledge in "the falls" near Hatcher's Rock.

Since the 1st of July, 1873, the work on Hatcher's Rock and the Point of Ledge, near it, has been carried on with commendable energy by the

contractor and satisfactorily completed in accordance with the requirements of the contract of August 26, 1872, in addition to which, 85 cubic yards of sunken ledge have been removed from "the falls," as authorized by the Department, on the same terms as contained in the contract, viz, $35 per cubic yard. The foregoing work was completed in December, 1873, leaving a balance available for additional work of $3,951.41.

By the extension of the survey made in November, 1873, of "the falls," several dangerous sunken ledges were discovered, which it was decided should be removed, the work to be done by contract after advertising for proposals therefor. On the 1st of May, 1874, a contract was made with Mr. Edouard M. LeProhon, of Portland, Me., for the removal of these ledges to a depth of 7 feet below mean low-water, (altogether about 106 cubic yards,) at $34 per cubic yard, as measured *in situ*. In the latter part of June operations were commenced under this contract.

The progress made in the improvement of this river and "the falls," up to the 1st of July, 1874, therefore, consists in—

1. The removal of Hatcher's Rock and the Point of Ledge near it, together with 85 cubic yards of sunken ledge in "the falls," to a depth of 7 feet below mean low-water, or 11½ feet below mean high-water.
2. The removal, to a depth of 10 feet below mean low-water, of three bridge-piers above "the falls," affording a channel for that depth, 350 feet in width.
3. Wrought-iron spindles, with day-marks, have been placed upon Half-Tide Rock and Low-Water Rock, about one mile below Sullivan, and a spar-buoy on Crabtree Ledge, near the mouth of the river. Two spar-buoys have also been placed to mark the new channel opened through the bridge-piers.

In addition to the foregoing work, a contract has been made for the removal of all the remaining dangerous sunken ledges from the channel of "the falls," to a depth of 7 feet at mean low-water, to be completed on or before the 1st of September, 1874.

This comprises all the work that is projected for the improvement of this river and "the falls," for doing which the available funds are sufficient.

Financial statement.

Balance in Treasury of the United States July 1, 1873	$16,000 00
Amount in hands of officer and subject to his check, (including $1,200 percentage due on contracts not yet completed)	1,852 03
Amount expended during the fiscal year ending June 30, 1874	13,921 30
Amount available July 1, 1874	3,930 73

Y 5.

IMPROVEMENT OF PENOBSCOT RIVER, MAINE.

The navigation of this river has hitherto been much obstructed by sunken rocks and shoals in the harbor of Bangor, and as far down as Crosby's Narrows, distant about three and one-half miles. These shoals are chiefly composed of slabs, edgings, and sawdust thrown in from the numerous saw-mills at Bangor and above. The sunken rocks are all in the harbor of Bangor, and are known as Independence Rock, Steamboat Wharf Ledge, ledge off Dole's Planing-Mill Wharf, Green's Pier Ledge, and others.

The work projected for the improvement of this river consists—

1. In enlarging and straightening its channel through the several bars and shoals, so as to have a width of not less than 200 feet and a depth of 12 feet below the plane of low-water (or 25 feet at high-water) in the lowest stages of the river; and

2. In breaking up and removing all the sunken rocks down to a level of the general bed of the river, so as to have not less than 7 feet of water over them at low-water in the lowest stages of the river, which will give about 9 feet in its ordinary summer stage, except for Green's Pier Ledge, which is to have but 5 feet over it at mean low-water.

For this work the following appropriations have been made, viz:

By act of Congress approved July 11, 1870	$15,000 00
By act of Congress approved March 3, 1871	50,000 00
By act of Congress approved June 10, 1872	40,000 00
By act of Congress approved March 3, 1873	20,000 00
By act of Congress approved June 23, 1874	20,000 00
Total	145,000 00

Of this amount there had been expended, up to July 1, 1873, the sum of $52,189.93.

The progress made in this work, up to July 1, 1874, is as follows, viz:

I.—SUNKEN ROCKS.

	Tons.
1. Removed from Steamboat Wharf Ledge, about	1,000
2. Removed from Independence Rock, about	800
3. Gulliver's Rock, wholly removed, about	80
4. Green's Pier (outer) Ledge, about	115

The above work was done previous to July 1, 1872, after which (August 26, 1872,) a contract was made with Mr. George W. Townsend, of Boston, Mass., (the only bidder,) for removing to the required depth the remaining portions of the following ledges, at the prices stated, viz:

1. Independence Rock, (106 cubic yards)	$7,440 00
2. Steamboat Wharf Ledge, (150 cubic yards)	6,000 00
3. Ledge off Dole's Planing-Mill Wharf, (194 cubic yards)	7,760 00
Total, (530 cubic yards)	21,200 00

Under this contract the removal of Steamboat Wharf Ledge was completed in September, 1873, to the depth called for; the removal of eth ledge off Dole's Planing-Mill Wharf and of Independence Rock is nearly completed, with a probability that both will be completed before the close of the present season.

A contract was also made on the 21st of June, 1873, with Mr. George A. Bailey, of Boston, Mass., for the removal of about 500 cubic yards of Green's Pier Ledge, at $29 per cubic yard, measured *in situ*. This work has been deferred until the removal of the overlying mass of logs, ballast, &c., which, having recently been completed, it is probable that work upon the ledge itself will be commenced at an early day.

II.—SHOALS.

On the 31st of May, 1873, a contract was made with Messrs. Curtis, Fobes & Co., of Portland, Me., for removing from the channel near Bangor about 30,000 cubic yards of slabs, edgings, &c. They were subsequently obliged to build a dredging-machine, with scows specially adapted to this work, so that they were not able to commence operations until the middle of September, 1873, which, however, they were forced to suspend on the 23d of October following, owing to the high stage of the river. The very unusual continuance of the freshet has prevented the resumption of dredging operations since that time.*

Very slow and unsatisfactory progress has been made since 1871, under the Boschke contract of May 27, 1871, and nothing whatever has been done under it since 1872, although every reasonable facility has

*Dredging operations were resumed July 9, 1874, with favorable results.

been afforded in extension of time and otherwise. There being, moreover, sufficient grounds for believing that the original contractor had transferred all his interest to other parties who had not the requisite facilities and means for continuing the work, and all the machinery which had previously been used on the work having passed into other hands, it was decided to annul the contract, under the authority therein contained, as reported to the Department in letter of June 8, 1874.

The present condition of the work projected for the improvement of this river is as follows, viz:

Contracts have been made for removing—

1. All the sunken ledges, some of which have been removed, and the remainder probably will be before the close of the present season, with the exception of Green's Pier Ledge, on which some progress will be made, with a probability of its completion early next season.

2. Contracts have also been made for the removal, to the extent contemplated, of all the shoals formed by the accumulation of slabs, edgings, &c.

So that the only work that now remains to be provided for, in order to complete the projected improvement of this river, consists in the excavation of a channel through the gravel-bar opposite the city of Bangor, (which at present has but 6 feet of water over it at mean low-water in the lowest stages of the river,) so as to have a depth of 12 feet in those stages for a width of 200 feet. This work will require the excavation of about 90,000 cubic yards of gravel and sand, with some bowlders, the estimated cost of which, including contingencies, is $70,000.

The amount of funds that are available for the improvement of this river July 1, 1874, (including percentage due on contracts not yet completed,) is	$83,014 99
Of this amount, the following sums are required to meet the unfinished contracts, viz:	
1. Removal of Independence Rock	7,440 00
2. Removal of ledge off Dole's planing-mill wharf	7,760 00
3. Removal of Green's Pier Ledge, say	15,000 00
4. Excavation of slabs and edgings, under contract of May 31, 1873	25,000 00
5. Retained percentage on unfinished contracts	1,200 00
6. Contingencies, say	6,614 99
Total	63,014 99
Leaving available for removing the gravel-bar at Bangor*	20,000 00
Additional amount required for its completion	50,000 00

which amount could be expended therein to advantage during the fiscal year ending June 30, 1876.

The attention of the Department is respectfully called to the necessity for some legislation or action on the part of the United States Government to prevent further injury and obstruction to the navigation of this river by the throwing in of mill-waste. At the present time an enormous quantity of sawdust is being daily thrown into the river by certain mill-owners near Bangor, to the very great injury of its navigation, which it is more than probable the United States Government will be called upon at no distant day to remove.

Financial statement.

Balance in Treasury of United States July 1, 1873	$60,000 00
Amount in hands of officer and subject to his check	12,810 07
Amount appropriated by act approved June 23, 1874	20,000 00
Amount expended during the fiscal year ending June 30, 1874	9,795 08
Amount available July 1, 1874	81,814 99
Amount required for the fiscal year ending June 30, 1876	50,000 00

* Proposals were received for this work on the 15th of August, 1874, and the contract was awarded to Messrs. Curtis, Fobes & Co. (the lowest responsible bidders) for 25,000 cubic yards of dredging, at 73 cents per cubic yard.

Y 6.

IMPROVEMENT OF CAMDEN HARBOR, MAINE.

The work projected for the improvement of this harbor consists in—

1. Regulating the entrance, by dredging, between Portland steamer and Sanford's steamer wharves, and dredging a channel 100 feet wide, 1,000 feet long, and 7 feet deep at mean low-water from said entrance to the head of the wharves on the easterly side of the harbor; amount of excavation	46,500 cubic yards.
2. For dredging a channel 60 feet wide, 1,400 feet long, and 4 feet deep at mean low-water, on westerly side of the harbor to the head of the wharves, and connecting with the above-mentioned improvements; amount of excavation	13,500 cubic yards.
Addition of 25 per cent. for loosening of material by dredging	15,000 cubic yards.
Total	75,000 cubic yards.
The estimated cost of which, at 40 cents per cubic yard, is	$30,000
Adding for engineering expenses and other contingencies	3,000
Total	33,000
By act of Congress approved March 3, 1873, there was appropriated for the improvement of this harbor the sum of	$10,000
And by act of June 23, 1874	10,000
Total	20,000

In conformity with a project for improving this harbor under the appropriation of March 3, 1873, a contract was made May 14, 1873, with Mr. Franklin Mead, of Littleton, Mass., for 20,000 cubic yards, more or less, of dredging, at 40 cents per cubic yard. On the 25th of July, 1873, operations were commenced under this contract, and were continued to completion on the 25th of October, 1873, resulting in 22,753 cubic yards of dredging. By this work, whereby the appropriation was wholly exhausted, a good channel was opened to a depth of not less than 7 feet at mean low-water, (or 16½ feet at mean high-water,) and for a width of 50 feet and more, extending from deep water near the Portland steamer wharf to above the upper wharves on the eastern side of the harbor.

The appropriation of $10,000, made by act of June 23, 1874, is to be applied as follows, viz:

1. Opening the channel on the western side of the harbor, up as far as contemplated, (viz, Alden's wharf,) for a width of 50 feet and a depth of 4 feet at mean low-water, above Carleton's wharf, and increasing from 4 feet to 7 (below Carleton's wharf) for a distance of about 300 feet until it meets the new eastern 7-foot channel, requiring the dredging of about 16,000 cubic yards	16,000 cubic yards.
2. Widening the lower portion of the new eastern channel below where it meets the proposed western channel, requiring the dredging of about	6,000 cubic yards.
3. Deepening the harbor near Sanford's steamer wharf, below the 7-foot curve, to a depth of 9 feet, as originally contemplated, about	1,000 cubic yards.
Total	23,000 cubic yards.

This work is to be done by contract, after inviting proposals therefor.*

* Proposals for this work were opened on the 15th of August, 1874, and the contract was awarded to Mr. Augustus R. Wright (the lowest of two bidders) for 32,000 cubic yards, more or less, at 28 cents per cubic yard.

Financial statement.

Balance in Treasury of United States July 1, 1873	$9,000 00
Amount in hands of officer and subject to his check	948 63
Amount appropriated by act approved June 23, 1874	10,000 00
Amount expended during the fiscal year ending June 30, 1874	9,948 63
Amount available July 1, 1874	10,000 00
Amount required for the fiscal year ending June 30, 1876	13,000 00

Y 7.

IMPROVEMENT OF KENNEBEC RIVER, MAINE.

All the projected improvements of this river above Richmond were completed prior to June 30, 1873, as described in the annual report for the fiscal year ending that date, whereby a safe and unobstructed channel, not less than 100 feet in width and 10 feet in depth at mean low-water, (or 15½ feet at mean high-water,) in its low summer stages, had been completed from Richmond up to Gardiner, and thence to Augusta a channel 100 feet in width and not less than 6½ feet in depth at low-water, (or 11 feet at high-water,) in its lowest summer stages. The several appropriations made for this purpose from June 23, 1866, up to July 1, 1873, amounted to $115,000, of which there was then available $15,482.80, to be, in part, applied under the contract made May 21, 1873, with Edouard M. LeProhon, of Portland, Me., to the removal of Half-Tide Rock from the channel at the Narrows, below Richmond. This work was commenced in June and continued by him until November, 1873, when, on an inspection of the work, it was reported completed to a depth of 12 feet at mean low-water, as called for by the contract.

In order to obtain more accurate information of the Narrows, with a view to its further improvement, a very careful survey of it, throughout its whole extent, has since been made, by which it is shown that the only work that remains to be done, in addition to that heretofore contracted for, consists in the removal from the channel of the following sunken ledges, viz:

1. The three ledges marked III, IV, and V, on the drawing submitted to the Department, which contain about 70 cubic yards above the plane 12 feet below mean low-water, the estimated cost of which, at $40 per cubic yard, being	$2,800 00
Adding for contingencies, say	687 75
Total	3,487 75
2. Dry Rock, which contains, above the 12-foot plane, 1,850 cubic yards, the estimated cost of which, at $20 per cubic yard, being	$37,000 00
Adding for contingencies, say	3,500 00
Total	40,500 00
Of the above amount available for this work July 1, 1873, viz	$15,482 80
There was expended, during the fiscal year ending June 30, 1874	9,495 05
Leaving available for the removal of ledges III, IV, V, and Dry Rock, the sum of	5,987 75
By act of June 23, 1874, there was appropriated, for continuing this work, the additional sum of	12,000 00
Making a total, available July 1, 1874	17,987 75

Of this amount it has been decided to apply to the removal of ledges III, IV, and V* the sum of	$3,487 75
Leaving available for the partial removal of Dry Rock	14,500 00

but not to be applied thereto until the additional sum required for its completion, (viz, $26,000,) be appropriated therefor.

Financial statement.

Balance in Treasury of United States July 1, 1873	$14,000 00
Amount in hands of officer and subject to his check	1,482 80
Amount appropriated by act approved June 23, 1874	12,000 00
Amount expended during the fiscal year ending June 30, 1874	9,495 05
Amount available July 1, 1874	17,987 75
Amount required for the fiscal year ending June 30, 1876	26,000 00

Y 8.

IMPROVEMENT OF PORTLAND HARBOR, MAINE.

The following appropriations have been made for the improvement of this harbor, viz:

By act of Congress approved June 23, 1866		$105,111 05
By act of Congress approved July 11, 1870		10,000 00
By act of Congress approved March 3, 1871		40,000 00
By act of Congress approved June 10, 1872		45,000 00
By act of Congress approved March 3, 1873		50,000 00
By act of Congress approved June 23, 1874		20,000 00
Total		270,111 05
Amount expended up to July 1, 1873	$160,671 86	
Amount expended during the fiscal year ending June 30, 1874	41,113 20	
		201,785 06
Amount available July 1, 1874		68,325 99

On the 1st of July, 1873, the following work had been done for the improvement of this harbor, viz:

1. The capping of the breakwater extended for a length of 733½ feet, leaving 217 linear feet yet to be done.
2. A channel dredged through the Middle Ground Bar, to a width of 500 feet and to a depth of 21–22 feet at mean low-water, or 31 feet at ordinary high-water.
3. A channel dredged through the Spit opposite the Grand Trunk Railway wharves, so as to be 100 feet in width at its inner end and 200 feet at its outer end, with a depth of 20 feet at mean low-water.

Contracts had also been made for the following additional work in the harbor, viz:

1. August 23, 1872, with Messrs. Frank N. Lord, of Rochester, N. Y., and Augustus R. Wright, of Geneva, N. Y., for building the granite pier at the outer extremity of the breakwater for the sum of $9,750, and for furnishing materials and building 200 linear feet, more or less, of granite-capping for the breakwater extension, at $22.50 per linear foot.
2. August 22, 1872, with Messrs. Rufus A. Soule and Hugh Bowen, of Cumberland, Me., for furnishing and placing 5,000 tons, more or less, of stone, as foundation for the breakwater extension, at $1.20 per ton of 2,240 pounds.
3. September 17, 1872, with Messrs. John B. Curtis and George C. Fobes, (constituting the firm of Curtis & Fobes,) of Portland, Me., for 25,000 cubic yards, more or less, of dredging in Back Bay, at 25 cents per cubic yard, as measured in the scows.
4. May 10, 1873, with Mr. Augustus R. Wright, of Geneva, N. Y.

a. For dredging in front of Grand Trunk wharves (about 13,000 cubic yards) to a

* On the 13th of August, the day on which proposals were invited for this work, a contract for the same was awarded to Messrs. Edouard M. Le Prohon & Co., of Portland, Me., at $33.50 per cubic yard.

depth of 20 feet at mean low-water, for 50 cents per cubic yard, as measured in the scows.

b. For dredging in front of harbor commissioners' line from Atlantic up to Central wharf, (about 63,000 cubic yards,) and still farther if required (not to exceed 80,000 cubic yards additional) above Central wharf, to a depth of 16 feet at mean low-water, for 35 cents per cubic yard, as measured in the scows.

The only work done under these contracts, on the 1st of July, 1873, consisted in furnishing and laying 2,749$\frac{240}{2240}$ tons of rubble-stone for the foundation of the breakwater extension, and in laying the foundation and one course of cut-stone of the terminal pier.

Since the 1st of July, 1873, the work done under these contracts is as follows:

1. *Granite Pier.*—Work was continued upon this pier until the 1st of October, 1873, when it was completed in accordance with the contract.

2. The foundation of the breakwater has also been completed by the furnishing and laying of 1,016$\frac{1760}{2240}$ tons of rubble-stone, making altogether 3,766$\frac{1760}{2240}$ tons furnished under the contract.

3. The granite capping for the breakwater extension has also been completed, the length of same being 217 feet.

4. The work in Back Bay has been completed by the dredging of 24,938 cubic yards, whereby a channel has been opened to a width of 100 feet and a depth of 8 feet at mean low-water from Tukey's Bridge up to the stone-shed wharves.

5. The dredging in front of the harbor commissioners' line (in the inner harbor) was commenced by Mr. Wright, under his contract of May 10, 1873, on the 30th of September, 1873, since which time it has been prosecuted with energy—49,609 cubic yards having been dredged by him on the 1st of July, 1874.

6. The sunken wreck in the main ship-channel, below Forts Preble and Scammel, was blasted and scattered into deep water, so as to have a depth over it of not less than 35 feet at mean low-water.

7. The foundation of the oldest portion of the breakwater was repaired throughout its whole extent, where necessary—the work having been done with hired labor.

From the foregoing it is seen that all the work that has been projected for the improvement of this harbor has been completed, with the exception of the dredging in front of the harbor commissioners' line in the inner harbor.

The unexpended balance of the appropriations, made prior to June 23, 1874, for the improvement of this harbor, is	$48,325 99
Of which there is due for retained percentage on dredging done to date by Augustus R. Wright, under his contract of May 10, 1873	3,509 62
Leaving available for additional work under the contract	44,816 37
Of which there will be required to complete the dredging contracted for in front of the Grand Trunk wharves, and *below* Central wharf, about	14,816 37
Leaving available for dredging *above* Central wharf, to be done under the existing contract with Mr. Wright, if called for	30,000 00

But it is not deemed advisable to continue the work *above* Central wharf until Brown's, Smith's, and Hobson's wharves above shall have been removed as far inward as the harbor-commissioner's line, for the reasons set forth in my letter of December 28, 1872, to the committee of the Portland Board of Trade, a copy of which accompanied my annual report for the fiscal year ending June 30, 1873. And for the same reason it has been decided to postpone similar work for which the appropriation of $20,000 made by act of June 23, 1874, is also available.

It is more than probable that these obstructions will be removed at an early day, as steps have already been taken to that end, in which event the contemplated dredging will soon be completed to the extent of the amount available therefor.

The additional amount that will be required for *completing* this improvement to the extent projected, will be $30,000, which is the balance of the original estimate, which amount can be profitably expended upon the work during the fiscal year ending June 30, 1876.

The above-named works are situated in Portland Harbor, in the collection-district of Portland and Falmouth.

The following statement, furnished by the United States collector of customs, exhibits the "duties on imports, tonnage, and hospital dues assessed and collected at this port, for the fiscal year ending June 30, 1874:

Duties assessed		$10,249,073 90
Duties collected		576,025 54
Tonnage dues collected	$21,906 60	
Hospital dues collected	3,495 08	
		25,401 68

"The duties assessed, as well as those actually collected, measure the business of this port. The goods on which duties were assessed and not collected, were imported for transportation to other ports in the United States, or for exportation."

It is understood that the business of the port will be larger the current year than it was the last, as a new line of steamships is promised next autumn; a new railroad to Canada and the West will probably be opened for traffic in the year 1876.

Financial statement.

Balance in Treasury of the United States July 1, 1873	$80,000 00
Amount in hands of officer and subject to his check, (including $727.07 percentage due on contracts not yet completed)	9,439 19
Amount appropriated by act approved June 23, 1874	20,000 00
Amount expended during the fiscal year ending June 30, 1874	41,113 20
Amount available July 1, 1874	64,816 37
Amount required for the fiscal year ending June 30, 1876	30,000 00

Y 9.

IMPROVEMENT OF RICHMOND'S ISLAND, MAINE.

The work projected for this place consists in making a harbor of refuge, by means of a stone breakwater, connecting the island with the main-land, the length of the breakwater to be 2,000 feet, with an average thickness of 30 feet, and a height of 13 feet above mean low-water.

The harbor to be formed by this breakwater will afford safe anchorage and good holding-ground for vessels of the largest class, with the wind from any point except from the southwest. As the winds from the northward and eastward bring the most violent and destructive gales which occur on this coast, there can be no question as to the great benefit to be derived from this work in affording a refuge to vessels which are prevented by those storms from entering Portland Harbor (twelve miles to the eastward) or other places on this part of the coast.

The following appropriations have been made by Congress for this work, viz:

By act of June 10, 1872	$20,000
By act of March 3, 1873	60,000
Total	80,000

The following contracts have been made with the lowest responsible bidders for furnishing stone for this work, viz:

1. With Mr. Edward Moore, of Portland, Me., August 22, 1872, for furnishing and depositing 15,000 tons, more or less, upon the work, at $1.24 per ton of 2,240 pounds, under the appropriation of June 10, 1872;
2. With Mr. James M. Andrews, of Biddeford, Me., May 26, 1873, for furnishing and depositing 25,000 tons, more or less, of large quarry grout, at $1.75 per ton of 2,240 pounds, under the appropriation of March 3, 1873; and
3. With Mr. Isaac Hamilton, of Portland, Me., May 26, 1873, for furnishing and depositing 6,000 tons, more or less, of small bowlders, at $1.59 per ton of 2,240 pounds, under the appropriation of March 3, 1873.

On the 1st of July, 1873, the quantity of stone furnished under these contracts was as follows, viz:

8,714½⁹⁰⁰⁄₂₄₀ tons by Mr. Moore, under contract of August 22, 1872.
1,144²⁴⁰⁄₂₄₀ tons by Mr. Andrews, under contract of May 26, 1873.

In addition to the above the following has been furnished during the fiscal year ending June 30, 1874, viz:

1. 6,298 tons, by Mr. Moore, under his contract of August 22, 1872, making a total of 15,012½⁹⁰⁰⁄₂₄₀ tons furnished in completion of his contract, on the 30th of August, 1873.
2. 24,845½¹²⁰⁰⁄₂₄₀ tons, by Mr. Andrews, under his contract of May 26, 1873, making a total of 25,989½⁹⁴⁰⁄₂₄₀ tons, furnished in completion of his contract.
3. 2,186½¹³⁰⁄₂₄₀ tons of small stone by Mr. Hamilton, under his contract of May 26, 1873;* making the total quantity furnished during the year 33,330³³⁰⁄₂₄₀ tons, and the total to June 30, 1874, 43,189½¹⁵⁰⁄₂₄₀ tons. Mr. Hamilton has still to deliver about 4,000 tons; making a total in completion of his contract of about 6,200 tons. The original estimate for this work called for 60,000 tons of stone; so that about 13,000 tons more will be required for its completion; the estimated cost of which, at $1.75 per ton (the price of that last contracted for) is $22,750

Adding for contingencies, say 2,250

Makes the total amount required for its completion 25,000

Which could be profitably expended during the fiscal year ending June 30, 1876.

Financial statement.

Balance in Treasury of United States July 1, 1873	$65,000 00
Amount in hands of officer and subject to his check, (including $2,561.55 percentage due on contracts not yet completed)	4,972 36
Amount expended during the fiscal year ending June 30, 1874	60,708 49
Amount available July 1, 1874	8,568 53
Amount required for the fiscal year ending June 30, 1876	25,000 00

Y 10.

IMPROVEMENT OF SACO RIVER, MAINE.

The following appropriations have been made, from June 23, 1866, to date, for the improvement of this river, viz:

By act of Congress, approved June 23, 1866	$40,000
By act of Congress, approved March 2, 1867	40,000
Allotted under act of Congress, approved July 25, 1868	20,000
Allotted under act of Congress, approved April 10, 1869	22,500
By act of Congress, approved July 11, 1870	10,000
By act of Congress, approved March 3, 1871	15,000
By act of Congress, approved June 10, 1872	15,000
Total	162,500
Of which there was available July 1, 1873	$5,896 20

The work done up to 1st of July, 1873, was as follows, viz:

1. The breakwater at the mouth of the river was completed to the extent at present contemplated, in June 1873, under six separate contracts, by which there was furnished upon the work 81,125½²²⁰⁄₂₄₀ gross tons or 90,860½⁴⁴⁶⁄₂₀₀ net tons of stone, making a breakwater 4,200 feet in length, with an average thickness of about 20 feet, and a height of 10 feet above mean low-water.
2. Dangerous sunken rocks removed from the channel near Little Islands.

* On the 31st of August, 1874, Mr. Hamilton had furnished all the stone required for the completion of his contract, whereby the whole appropriation was exhausted.

3. A channel 50 feet wide was excavated through the bars below the wharves of Saco and Biddeford to a depth of 5 feet below mean low-water (giving 13¼ feet at ordinary high-water) in the summer stage of the river, in which about 4,000 cubic yards of slabs, edgings, &c., were excavated and removed from the bars.

4. A large wrought-iron spindle, 20 feet long and 14 inches in diameter, surmounted with an iron day-mark 8 feet in height, was placed to mark the toot of Cow Island Ledge in place of old pier No. 1.

5. A new pier was built on the point of ledge at Ferry Narrows, on the site of old pier No. 8. It is made of hewn pine logs, well framed and braced, and filled to its top with stone, and covered on its outer face with oak and pine 3-inch plank. It is 143 feet in length, 12 feet in height above mean low-water, and 15 feet in width on top, with a batter of one in 12 feet.

Another pier of the same description, 155 feet in length, was built nearly to completion on the ledge on Jordan's Point in the place of old pier No. 9. Upon this ledge a stone foundation was built up to the plane of mean low-water, (a height of from 2 to 4 feet,) and upon this the pier was built.

During the fiscal year ending June 30, 1874, the following additional work was done, viz:

The pier on Jordan's Point was completed July 31 to a height of 12 feet above mean low-water.

A similar pier, 130 feet in length, was commenced in August, 1873, on Ward's Point in the place of old pier No. 7, and was completed in September, 1873; and the old pier No. 2 (about one mile below Saco wharves) was thoroughly repaired, planked, and ballasted with stone, having been completed early in October, 1873.

The piers were all built and repaired with hired labor; and their completion finishes all the improvements that have heretofore been projected or this river.

The works for the improvement of Saco River are situated in the collection-district of Saco and Biddeford, Me. The nearest light-house is on Wood Island, opposite the mouth of Saco River; and the nearest forts are those in Portland Harbor, about fifteen miles distant.

The amount of revenue collected at Saco, the port of entry, during the fiscal year ending June 30, 1874, as furnished by the United States collector of customs, was $276.48.

The number of sea-going vessels which arrived during the same period was 219.

Financial statement.

Balance in Treasury of United States July 1, 1873	$5,000 00
Amount in hands of officer, and subject to his check	896 20
Amount expended during the fiscal year ending June 30, 1874	5,896 20

Y 11.

IMPROVEMENT OF WELLS HARBOR, MAINE.

The improvement projected for this harbor consisted in the repairs of an old Government pier at the mouth of Webhannet River. This pier was built from thirty to forty years ago for the purpose of straightening and deepening the channel over the bar at the entrance to this harbor. It was made of crib-work ballasted with stone, and was about 250 yards in length.

By an act of Congress approved June 10, 1872, the sum of $5,000 was appropriated for this work.

The projected repairs were commenced with hired labor in the latter part of September, 1872, and were completed on the 30th of June, 1873; and in September, 1873, they were entirely finished.

Financial statement.

Amount in hands of officer and subject to his check	$324 93
Amount expended during the fiscal year ending June 30, 1874	324 93

Y. 12.

IMPROVEMENT OF COCHECO RIVER, NEW HAMPSHIRE.

This river in its lowest summer stage is navigable from the harbor of Portsmouth, N. H., up to the Lower Narrows, (which place is distant one and one-half miles below the bridge at the head of navigation in Dover, N. H.,) with 6 feet at mean low-water, and 13½ feet at ordinary high-water. At the Lower Narrows, and above, its navigation has been obstructed by ledges, bowlders, and shoals, having only from 6 inches to 2 feet of water over them at mean low-water, the average rise of the tide being 6.8 feet at the Lower Narrows, and less above.

The following appropriations have been made for improving the navigation of this river, viz:

By act of Congress approved March 3, 1871	$10,000 00
By act of Congress approved June 10, 1872	10,000 00
By act of Congress approved March 3, 1873	10,000 00
By act of Congress approved June 23, 1874	10,000 00
Total	40,000 00
Of which amount there had been expended up to July 1, 1873, the sum of.	9,436 18
Amount available July 1, 1873	20,563 82

Up to this period, (viz, July 1, 1873,) the work done was as follows, viz:

1. A channel opened through the ledge at the Lower Narrows to a width of 75 feet, and a depth of 4 feet at mean low-water.
2. All the sunken rocks removed from the channel between the Lower and Upper Narrows.
3. Contracts had also been made with Mr. Edward Moore, of Portland, Me., the lowest responsible bidder, for the partial opening of a channel 40 feet in width and 4 feet in depth at mean low-water, through the ledge at the Upper Narrows, (or Gulf.)

These contracts provided for the removal of 772 cubic yards of ledge, at $26.50 per cubic yard. The contractor commenced operations in May, 1873, in building a coffer-dam, so as to inclose the whole work contracted for; which coffer-dam was completed in the latter part of August, when the water was pumped out and work commenced upon the excavation of the ledge. This work was prosecuted with commendable energy, and was very satisfactorily completed by the contractor, on the 31st of October, to the extent required under his two contracts, viz, the excavation and removal of 772 cubic yards of ledge.

By this work the channel has been opened to a width of 40 feet and a depth of 4 feet at mean low-water (giving 10.8 feet at ordinary high-water) for an extent of 300 feet through the Upper Narrows, leaving about 130 feet yet to be done under future appropriations.

In this work all the balance of the appropriations available July 1, 1873, has been entirely expended.

The sum of $10,000 appropriated by act of June 23, 1874, is to be applied to the completion of the channel, having the projected width and depth through the Upper Narrows, which will require about 500 cubic yards of ledge excavation.*

To complete all the improvements projected for this river, as stated in the annual report for the fiscal year ending June 30, 1873, will require the additional sum of $65,000, which can be profitably expended during the fiscal year ending June 30, 1876.

* A contract for this work was made on the 31st of July, 1874, with Mr. Edward Moore, of Portland, Me., (the only bidder,) at $20 per cubic yard.

Financial statement.

Balance in Treasury of United States July 1, 1873	$17,000 00
Amount in hands of officer and subject to his check	3,563 82
Amount appropriated by act approved June 23, 1874	10,000 00
Amount expended during the fiscal year ending June 30, 1874	20,563 82
Amount available July 1, 1874	10,000 00
Amount required for the fiscal year ending June 30, 1876	65,000 00

Y 13.

IMPROVEMENT OF MERRIMAC RIVER, INCLUDING THE HARBOR OF NEWBURYPORT, MASSACHUSETTS.

The following appropriations have been made for the improvement of Merrimac River, Mass., viz:

By act of July 11, 1870, for improvement of Merrimac River, Mass	$25,000 00
By act of March 3, 1871, for improvement of Merrimac River above Haverhill, Mass	25,000 00
By act of June 10, 1872, for improvement of Merrimac River above Haverhill, Mass	25,000 00
By act of March 3, 1873, for improvement of Merrimac River, Mass	25,000 00
By act of June 23, 1874, for continuing the improvement of Merrimac River, Mass	10,000 00
Total	110,000 00
Amount expended up to July 1, 1873	51,305 53
Amount available July 1, 1873	48,694 47

Up to July 1, 1873, the work done was as follows, viz:

1. The main (South) Gangeway Rock, in Newburyport Harbor, broken up and removed in 1870 to a depth of 9½ feet at mean low-water, and a commencement made upon North Gangeway Rock.

2. The wreck of the schooner Globe removed in 1870.

3. Four hundred and seventy-five cubic yards of clay, bowlders, &c., excavated and removed in 1870 from the channel of the Lower Falls above Haverhill; 2,100 cubic yards in 1871, and 156 cubic yards in June, 1873; making a total of 2,731 cubic yards, by which the work in these falls was about half completed.

4. The following contracts had also been made, under the appropriations of June 10, 1872, and March 3, 1873, with Mr. Augustus R. Wright, of Geneva, N. Y., the lowest bidder, for improving the channel in the Lower Falls, Hazletine Rapids, and the Upper Falls, viz:

a. By contract, dated September 9, 1872, for 4,400 cubic yards, more or less, of excavation in the Lower Falls and Hazletine Rapids, at $4.95 per cubic yard; and

b. By contract, dated May 30, 1873, for 5,000 cubic yards, more or less, of excavation in the Upper Falls, at $4.50 per cubic yard.

In June, 1873, 156 cubic yards were excavated in the Lower Falls, as stated above, under the contract of September 9, 1872, after which work was commenced (July 4) at the Upper Falls, under the contract of May 30, 1873.

This work was continued at the Upper Falls until the 21st of October, when, owing to the high stage of the river, it was suspended for the winter.

The dredging done to that date at the Upper Falls amounted to 3,755 cubic yards, leaving about 2,800 cubic yards to be done for its completion.*

* The dredging was completed at the Upper Falls in September, 1874.

Operations were resumed by Mr. Wright at the Lower Falls on the 29th of June, 1874, under his contract of September 9, 1872.

The following is an estimate of the cost of the work for completing the improvements now projected for this river and harbor of Newburyport, viz:

1. *Newburyport Harbor, at the mouth of Merrimac River.*

a. Complete removal of North Gangeway Rock, 700 cubic yards, at $20...	$14,000 00
b. Removing "the Boilers," near the city wharves	6,000 00
Adding for contingencies, say	2,000 00
Total	22,000 00

2. *River between Newburyport and Haverhill, Massachusetts.*

a. Removal of Gangeway Rock, 14 cubic yards, at $20	$280 00
b. Removal of two rocks, above Deer Island bridge, 108 cubic yards, at $20.	2,160 00
c. Removal of rocks at Rocks-Bridge	1,000 00
d. Removal of Little Currier Rock, 2 cubic yards	25 00
e. Dredging at Currier Shoal, 6,500 cubic yards, at 75 cents	4,875 00
f. Dike at Silby's Head, 350 feet, at $25	8,750 00
Adding for contingencies, say	1,910 00
Total	19,000 00

3. *River above Haverhill, Massachusetts.*

a. Excavating a channel, 60 feet wide, and 4 feet deep at low-water, in the summer stage of the river, at Hazletine Rapids, 1,900 cubic yards, at $4.95.	$9,405 00
b. Completing the channel to the same width and depth at the Upper Falls, 2,800 cubic yards, at $4.50	12,600 00
c. Completing the channel to the same width and depth at the Lower Falls, 2,500 cubic yards, at $4.95	12,375 00
Adding for contingencies, say	5,091 09
Total	39,471 09

Total amount required for completing all the projected improvements, as above		$80,471 09
Of which there is now available under existing appropriations.	$43,028 97	
Deducting amount of percentage retained on contract work...	3,557 88	
		39,471 09
Additional amount required		41,000 00

Financial statement.

Balance in Treasury of United States July 1, 1873	$45,000 00
Amount in hands of officer and subject to his check, (including $154 62 percentage due on contracts not yet completed)	3,694 47
Amount appropriated by act approved June 23, 1874	10,000 00
Amount expended during the fiscal year ending June 30, 1874	15,665 50
Amount available July 1, 1874	39,471 09
Amount required for fiscal year ending June 30, 1876	41,000 00

Y 14.

IMPROVEMENT OF GLOUCESTER HARBOR, MASSACHUSETTS.

By an act of Congress approved June 10, 1872, the sum of $10,000 was appropriated for the removing of rocks in this harbor. Under this

appropriation a contract was made August 26, 1872, with Mr. Geo. W. Townsend, of Boston, Mass., for removing the following sunken rocks, at the prices named, viz:

1. Babson's Ledge, at $20 per cubic yard.	
2. Clam Rock, at $20 per cubic yard	$450
3. Pinnacle Rocks, at $20 per cubic yard	1,170
4. Rocks off J. Friend's wharf, at $20 per cubic yard	330
5. Rock off Pew's wharf, at $20 per cubic yard	45

On the 1st of July, 1873, all the work contracted for was completed, viz:

1. Clam Rock, removed from a depth of 1 foot to that of 9½ feet below the plane of mean low-water, the level of the surrounding bottom.
2. Pinnacle Rocks, removed from 8½ feet above down to the level of the surrounding bottom, which has a depth of 16½ feet below the plane of mean low-water.
3. Rocks off J. Friend's wharf, removed down to the level of the surrounding bottom.
4. Rock off Pew's wharf was entirely removed to a depth of 5 feet below mean low-water; and
5. The largest bowlders were removed from the rocky shoal known as "Babson's Ledge."

Work has been suspended since July 1, 1873.

Amount available July 1, 1874, for additional work, $686.84.

Financial statement.

Amount in hands of officer and subject to his check	$9,479 64
Amount expended during the fiscal year ending June 30, 1874	8,783 80
Amount available July 1, 1874	686 84

Y 15.

IMPROVEMENT OF SALEM HARBOR, MASSACHUSETTS.

The following appropriations have been made by Congress for this work, viz:

By act of March 3, 1873	$15,000
By act of June 23, 1874	10,000
Total	25,000

The following is an estimate of the cost of the work projected for the improvement of this harbor, viz:

1. Excavating a channel 1,730 feet long, 300 feet wide, to a depth of 8 feet at mean low-water, (giving 17.3 feet at mean high-water,) from the entrance to South River outward to deep water, including contingencies	$25,000
2. Constructing a sea-wall and a breakwater for the preservation and protection of Long Point, including contingencies	23,000
Total	48,000

After advertising for proposals, a contract was made May 1, 1873, with Mr. Augustus R. Wright, of Geneva, N. Y., the lowest of four bidders, for 30,000 cubic yards, more or less, of dredging, at 44 cents per cubic yard, as measured in the scows. On the 10th of May he commenced work, and up to the close of the fiscal year ending June 30, 1873, he had dredged 9,266½ cubic yards under this contract. After a suspension of work on the 5th of June, it was resumed on the 8th of December, from which date up to the 10th of March, 1874, 22,229½

cubic yards of dredging was done, making a total of 31,496 cubic yards in completion of the contract. By this work the channel has been opened to the required depth of 8 feet at mean low-water from the mouth of South River outward to deep water for an average width of 160 feet.

The appropriation made by act of June 23, 1874, will, it is believed, be sufficient to complete all the dredging necessary for improving the channel from deep water to the entrance of South River.*

Financial statement.

Balance in Treasury of United States July 1, 1873	$8,000 00
Amount in hands of officer and subject to his check, (including $815.54 percentage due on contracts not yet completed)	3,455 51
Amount appropriated by act approved June 23, 1874	10,000 00
Amount expended during the fiscal year ending June 30, 1874	11,455 51
Amount available July 1, 1874	10,000 00
Amount required for the fiscal year ending June 30, 1876	23,000 00

Y 16.

IMPROVEMENT OF BOSTON HARBOR, MASSACHUSETTS.

The several works projected and in progress for the improvement and preservation of this harbor consist of the following, viz:

1. The sea-wall for the protection and preservation of Point Allerton.
2. The sea-wall for the protection and preservation of Great Brewster Island.
3. The sea-walls for the protection and preservation of Lovell's Island.
4. The sea-wall for the protection and preservation of Gallop's Island.
5. The sea-wall for the protection and preservation of the north head of Long Island.
6. The sea-walls for the protection and preservation of Deer Island.
7. Straightening, widening, and deepening the main ship-channel in the Narrows.
   (*a*.) At the west end of Great Brewster Bar;
   (*b*.) At the southeast point of Lovell's Island; and,
   (*c*.) At the southwest point of Lovell's Island.
8. Widening and deepening the channel through the Upper Middle Bar.
9. Removal of Nash's Rock.
10. Completing the removal of Kelly's Rock.
11. Removal of a sunken ledge, situated in "The Narrows," between George's Island and Great Brewster Spit.
12. Removal of State and Palmyra Rocks, on the southern spurs of the Lower Middle.
13. Surveys of sunken rocks.

1. *Sea-wall on Point Allerton.*—Work was commenced upon this sea-wall in September, 1870, and was completed in May, 1874, having been built, for the most part, under four separate contracts with Mr. James M. Andrews, of Biddeford, Me., made respectively May 24, 1870, July 26, 1871, August 24, 1872, and May 8, 1873. The last contract provided for completing this sea-wall at the same prices as in the previous contracts, viz:

1. Granite wall, (including granite facing and coping, concrete foundation and backing,) at $77.90 per linear foot.
2. Concrete for additional foundation, if required in excess of that called for by the drawings and specifications, at $11 per cubic yard.
3. Excavation for foundation, at $1 per cubic yard.
4. Back filling of earth, at 50 cents per cubic yard.
5. Paving, (including paving-stones and cobble-stones, shingle, and gravel for bedding for same,) at $6.40 per superficial yard.

* A contract for this work was made September 5, 1874, with Messrs. Curtis, Fobes & Co., of Portland, Me., to be completed May 1, 1875.

The contractor commenced work, under his last contract, early in May, 1873, and up to June 30 of that year he had finished 145 linear feet of granite wall, 593¾ cubic yards of excavation for the foundation, and 2,008 cubic yards of back-filling.

This work was continued by him from July 1 until December 12, 1873, when it was suspended until March, and then resumed and continued until its completion on the last of May, 1874. During this period the following additional work was done, viz: 132.21 linear feet of granite wall, completed in August, 1873, to the projected length of 1,202½ feet; 595.58 cubic yards of excavation for the foundation, completed in August, 1873; 3,351½ cubic yards of earth back-filling; and 1,905 superficial yards of granite paving. The total quantity of work done under the contract of May 8, 1873, in completion of the sea-wall, was as follows, viz: 277.2 linear feet of granite wall; 1,189⅓ cubic yards of excavation for the foundation; 5,359½ cubic yards of earth back-filling; 1,905 superficial yards of granite paving.

In addition to the above contract work, there have been built since July 1, 1873, for the protection of the concrete foundation of this sea-wall, where most exposed to injury by storms and currents, 1,005 linear feet of granite apron, and eight jetties, in which has been placed 1.598.94 tons of granite grout. This apron has an average width of about 10 feet, is from 2 to 3 feet in height, and extends all along the fourth, fifth, sixth, seventh, and eighth faces, counting from the east, and for about 50 feet along the first face, and along the western wing-wall, in order to protect its junction with the shore crest. The several jetties have a length of 25 to 30 feet, a width of about 6 to 8 feet, and a height of 2 to 3 feet, and are placed, five at the fourth, fifth, sixth, seventh, and eighth angles, two from the middle of the first and seventh faces, and one at the easterly wing-wall, also serving as a ramp. The granite grout of which this apron and the jetties are built has been furnished and placed in position, at $3.25 per ton, as authorized by Department letter of July 23, 1873. The total length of this sea-wall, as completed, is 1,202½ feet.

2. *Sea-wall on Great Brewster Island.*—This wall, 2,800 feet in length, was built for the protection of the north and south heads of the island, and fully answers the purpose intended. It was commenced in 1849, and was continued through the year 1850, when work upon it was suspended. Since then it has been continued from time to time as appropriations have been made for it. It is now in good condition, not requiring any repairs.

3. *Sea-walls on Lovell's Island.*—There are two sea-walls on this island, one of which was built thirty years ago, for the protection of its north head, and the other in 1867 and 1868 for the protection of the southeast bluff for a length of about 800 feet. An inspection of these sea-walls, made in the latter part of March, 1873, showed—

1. That the old wall on the north head was in good condition; but that the long jetty at its southern extremity was much shattered by the storms and currents, and that the shore-line south of the wall, for a distance of about 600 feet, had been much abraded of late years, to a degree threatening serious changes, the immediate prevention of which was absolutely necessary. For this purpose it was recommended that the jetty be repaired, and that an apron-work of large rubble-stone be built for the protection of the shore south of it for a length of 620 feet; and,

2. That the sea-wall at the southeast bluff was in good condition, not requiring any repair, but that the shore line next to its southern extremity had become worn away for a length of 110 feet, for the preservation of which a stone apron was recommended, to be 18 feet in width and 3 feet in height.

Work was commenced with hired labor upon the north wall in May, 1873, and was completed in July following; and the apron upon the shore next to the sea-wall at the southeast bluff was completed early in August, 1873.

4. *Sea-wall on Gallop's Island.*—The sea-wall is 1,745 feet in length. Work upon it was commenced in the year 1868, under a contract made May 26, 1868, with Mr. James Andrews, of Biddeford, Me., and was carried on under that contract until the end of April, 1871, after which it was continued with hired labor until its completion, in the latter part of September, 1871.

The violent storms and currents to which this wall is exposed had laid bare its concrete foundation to such a degree as to render necessary, for its protection and preservation, a stone apron throughout nearly its whole length, with jetties projecting outwards from its faces. This work was commenced in August, 1873, and completed in April, 1874. The apron extends along the base of this wall for a length of 1,655 feet, being on the most exposed faces of the wall 10 feet in width. Eight jetties have been built at and near the angles of the wall, of which five are of split granite, bedded in part in concrete, laid in trenches and surrounded with a concrete apron, each being 18 feet in length and 5 feet in width. The quantity of stone used in this work was about 1,450 tons.

5. *Sea-wall on the north head of Long Island.*—Work was commenced upon this sea-wall in August, 1870, and has been continued for the most part under contracts with Mr. James Andrews, of Biddeford, Me., made respectively May 24, 1870, July 26, 1871, August 23, 1872, and May 8, 1873, the last of which provided for completing this sea-wall at the same prices as in previous contracts, viz:

1. Granite wall, (including granite facing and coping, concrete foundation and backing,) at $58.19 per linear foot.
2. Concrete for additional foundation, if required, in excess of that called for by the drawings and specifications, at $10.25 per cubic yard.
3. Excavation for the foundation, at $1 per cubic yard.
4. Back-filling, at 50 cents per cubic yard.
5. Paving, (including paving-stones and cobble-stones, shingle and gravel for bedding for same,) at $5 per superficial yard.

The contractor commenced work under his last contract early in May, 1873, and up to 1st of July he had finished $161\frac{375}{1000}$ linear feet of granite wall proper, $558\frac{95}{100}$ cubic yards of excavation for the foundation, and 1,300 cubic yards of back-filling. Work was continued by him from July 1 until the 1st of December, 1873, when it was suspended until March, and then resumed and continued until its completion about the last of July, 1874.

During the fiscal year ending June 30, 1874, the work done under the contract of May 8, 1873, was as follows, viz:

Three hundred and eighty and one-third linear feet of granite wall, completed in September, 1873, to the projected length of 2,080 feet; 776¾ cubic yards of excavation for the foundation, completed in September, 1873; 3,770½ cubic yards of back-filling of earth placed behind the wall, and 3,038.6 superficial yards of granite paving laid. The total quantity of work done by Mr. James Andrews under his contract of May 8, 1873, up to the 1st of July, 1874, consisted of 541.7 linear feet of granite wall: $1,335\frac{77}{100}$ cubic yards of excavation for the foundation; 5,070½ cubic yards of earth back-filling, and $3,038\frac{6}{10}$ superficial yards of granite paving; leaving to be done under that contract for the entire completion of the wall, only 550 cubic yards of back-filling, and 353½ superficial yards of granite paving.

In addition to the above contract work, there have been built since about the 1st of April, 1874, for the protection of the concrete founda-

tion of this sea-wall where most exposed to injury by storms and currents, about 750 linear feet of stone apron and 7 jetties, leaving for completion 225 linear feet of apron work and 3 jetties.*

6. *Sea-walls on Deer Island.*—The three sea-walls on this island were built about thirty-five years ago for the protection and preservation of the north, middle, and south heads, and were respectively 1,740, 840, and 420 feet in length. The injury which these walls had sustained from the violence of the storms was such as to necessitate the rebuilding of them to a great extent. This was commenced in 1865 and completed in 1869; not, however, to the extent that has since proved to have been necessary. On an inspection of them it was found that in numerous places the stone in the lower course of the north head wall had been moved out of place; that the granite paving in the rear of this wall, for a length of 68 feet, had still to be completed, and that about 70 linear feet of the old paving required relaying, and that the wall otherwise needed repairs.

These repairs were taken in hand, with hired labor, on the 15th of October, and were completed early in November, 1873.

7. *Straightening, widening, and deepening the main ship-channel at "The Narrows."*—This work consists in the removal of portions of Brewster's Spit and Lovell's Island, so as to obtain a depth of 23 feet at mean low-water, for a width of 600 feet, with proper slopes up to the 18-foot curve.

Work was commenced on Lovell's Island in 1867, and continued during that and the two following years, until suspended for want of funds. The officer then in charge of this work reported that by these operations the whole southwest point of this island was cut off for a width of 260 feet from the top of the bank in a regular slope to a depth of 23 feet at mean low-water; and that the channel at that point had been widened at the depth of 18-foot curve from its former width of 365 feet to 625 feet.

With a view to ascertaining the condition of the channel in "The Narrows" and its vicinity, and what changes, if any, had taken place therein since the completion of the improvements there, including the enlargement of the channel at Lovell's Island, a resurvey of that locality was made under my direction, in July and August, 1872, by my assistant, Mr. H. F. Bothfeld, civil engineer, whose report thereon, and map, dated February 18, 1873, accompanied my report for the fiscal year ending June 30, 1873. On referring to this map it will be seen that the channel at the southwest point of Lovell's Island has not changed, to any considerable extent, since the dredging operations were closed in 1869; that the 18-foot curve is now very nearly the same as it was then; and that the shore above low-water line has acquired a more natural slope of 8 feet horizontal to 1 foot rise by the receding inland of the high-water line; also, that the flats off the southeast point of Lovell's Island have advanced so much toward the main channel as to materially impede and endanger navigation. It will also be seen that the extreme westerly end of Brewster's Spit has continued to extend in a westerly or southwesterly direction, the point on low-water line being 120 feet further out than in 1860, and the present 18-foot curve 168 feet from that of 1860.

The estimated cost of the improvement of "The Narrows" by the excavation from Lovell's Island to a depth of 23 feet at mean low-water, for a width of 600 feet, with proper slopes inward, and by excavating

* This work was entirely completed early in August, 1874.

Brewster's Spit, as shown on the drawing above referred to, is as follows, viz:

1. Brewster's Spit, 60,000 cubic yards dredging on westerly extremity of the spit, at 40 cents	$24,000 00
2. Lovell's Island, 40,000 cubic yards dredging on southeast point at 40 cents	16,000 00
3. Lovell's Island, 40,000 cubic yards dredging on southwest point at 40 cents	16,000 00
Total	56,000 00

The improvements projected at the west end of Great Brewster Bar and at the southeast point of Lovell's Island are at once to be taken in hand, under the appropriation for this harbor made by act of June 23, 1874.*

8. *Widening and deepening the channel through the "Upper Middle Bar."*—The improvement projected for this bar consists in opening through it a channel to a width of 600 feet, and a depth of 23 feet at mean low-water, the average length of the "cut" being 2,200 feet, with an excavation of from 1 to 7 feet.

The work done up to the 1st of July, 1873, amounted to the excavation of 46,425 cubic yards, by which an entire "cut" was completed to a width of 40 feet, and a length of 1,800 feet, and a second "cut" completed for a length of 1,040 feet, and to a depth of 23 feet at mean low-water, including the removal of a large bowlder, (discovered in the channel in 1872,) having but 16½ feet of water on it at mean low-water.

On the 27th of January, 1874, proposals were invited for 75,000 cubic yards, more or less, of dredging and rock-excavation, in continuation of this improvement, and a contract was made for the work on the 5th of March, 1874, with the Atlantic Dredging Company, of Brooklyn, N. Y., who were the lowest of four bidders, at 64 cents per cubic yard for dredging as measured in the scows, and $35 per cubic yard for the excavation of ledge and bowlders exceeding six tons in weight.

Operations were commenced under this contract early in April, 1864, and have since been continued; eight thousand four hundred and seventy-six cubic yards of dredging having been done up to the 1st of July, 1874, leaving about 66,500 cubic yards still to be done in completion of the contract.

The appropriation made by act of June 23, 1874, for continuing the improvement of this harbor, will be applied in part to continuing this work by contract after inviting proposals for the same. †

9. *Removal of Nash's Rock.*—Nash's Rock (so called) is a shoal lying in the outer entrance to Boston Harbor, about one-third of the way over from Brewster Spit to Point Allerton. This shoal was surveyed under my instructions, in September and October, 1873, by my assistant engineer, Mr. H. F. Bothfeld, and a special report thereon, accompanied by drawings, was submitted to the Department on the 24th of March, 1874. From information acquired by this survey it is seen that the only portion of this shoal which it would be advisable and practicable to improve, is that having less than 21 feet of water over it at mean low-water, which portion has an area of 637½ superficial yards, and would require, in order to obtain a depth of 21 feet, the excavation and removal of about 200 cubic yards of bowlders, shingle, &c., at an estimated

* Proposals were invited for this work, and contracts were made early in September, 1874—to be completed on or before the 30th June, 1875.

† A contract was made for this work September 1, 1874, with the Harbor Improvement Company, of Boston, for 42,000-55,000 cubic yards of dredging, at 85 cents per cubic yard, to be completed on or before the 15th of August, 1875.

cost of $5,000, whereas, to remove the whole shoal to a depth of 23 feet below the plane of mean low-water, would require the additional excavation of over 16,000 cubic yards of similar material over an area of 9$\frac{1}{6}$ acres, the cost of which would be greatly disproportionate to the benefit that would result therefrom.

10. *Completing the removal of Kelly's Rock.*—This rock lies in the main ship-channel, distant about 700 yards in a direction southeast by south from the Bug Light, (at the Narrows,) and in the line of entrance buoy No. 1 and Bug Light.

In the autumn of 1869 operations were commenced upon this ledge for its removal, by blasting to a depth of 23 feet below the plane of mean low-water, and they were continued up to the end of December, 1870. These operations were resumed in June, 1873, and were continued until the 25th of July following, during which time 118 tons of rock were removed. An accurate survey, since made, shows that there is still an area of about 320 superficial yards of this ledge which has less than the projected depth, on the shoalest parts of which there are but 21.2 feet of water at mean low-water. In order to obtain the full depth of 23 feet at mean low-water, the additional removal of not less than 80 cubic yards will be required, the estimated cost of which is $5,000. It is contemplated to have this work completed under the appropriation made for this harbor by act of June 23, 1874.

11. *Removal of Sunken Ledge, situated in the Narrows, between George's Island and Great Brewster Spit.*—This ledge was discovered in September, 1872, in a resurvey of "The Narrows," made under my direction, by my assistant, Mr. H. F. Bothfield, civil engineer, and a careful resurvey of it was made in July, 1873, a drawing of which has been furnished the Department. It is situated near the middle of the main ship-channel, directly in the track of all large vessels, and particularly of the European steamers, and is distant 317 yards in a direction west by south from Bug Light. It is an out-cropping of ledge of argillaceous slate, with its laminations much contorted. In its longest direction it lies obliquely to the channel, running from north to southeast by east for 41 feet, with an average width of nearly 10 feet, its highest point having but 18.9 feet of water upon it at mean low-water. Its area in the plane of 23 feet below mean low-water is 44$\frac{1}{3}$ square yards, and its cubic contents above this plane is 16$\frac{1}{8}$ cubic yards.

The removal of this ledge to a depth of 23 feet at mean low-water is recommended; the estimated cost of which is $500.

It is contemplated to have this ledge removed to a depth of 23 feet below mean low-water, under the appropriation of June 23, 1874.*

12. *Removal of State and Palmyra Rocks.*—A survey was made of these rocks in August, September, and October, 1873, by my assistant engineer, Mr. H. F. Bothfeld, under my direction and in accordance with my project submitted to the Department under date of April 2, 1873, of which a special report and drawings were transmitted to the Department on the 25th of May, 1874.

In this survey more than 2,100 soundings were made over an area of about 40,000 square yards, the greater part of which were over the shoal ground south of the line connecting the buoys Nos. 8 and 10, as shown upon the drawing. Forty borings were also made to ascertain the character of the bottom of the shoal. By this survey it was ascertained that State Rock and Palmyra Rock, of the position and character

*A contract was made for this work August 31, 1874, with Mr. William H. Lloyd, of Boston, who was the lowest of two bidders therefor, at $400 for the job, and early in September it was completed.

of which but little was previously known, are situated very near each other, and most probably are outcroppings of the same ledge, forming spurs on the southern side of the Lower Middle Bar, at the points marked A and B on the drawing, which are distant about one-half a mile due east from the wharf at Fort Independence. It was also ascertained that this shoal ground generally consists of a top layer of sand and shells, occasionally mixed with gravel and clay, averaging about one foot in thickness, with a substratum of grayish-blue clay or slate ledge. In several places from 2 to 3 feet of clay was penetrated before striking the ledge; whilst in others the ledge was bare.

As the main ship-channel is here about 800 feet wide, it is not deemed necessary to undertake its enlargement by a general excavation of this extensive shoal. But in order to increase the safety of navigation it is recommended that the most dangerous points of ledge and bowlders be removed from the southern part of this shoal to a depth of 14 feet below mean low-water, which is probably sufficient for such vessels as are liable to be benefited thereby.

For this purpose the removal of the following rocks will be necessary, viz:

a. At the point marked F on the drawing, that being the ledge on which the steamer Norman ran and stuck fast for two days, in 1869. Its highest point is 3.7 feet above the proposed 14-foot plane, and has an area in that plane of about 23 square yards, requiring the removal of about 12 cubic yards of ledge.

b. At the point marked G, where the ledge is 2⅝ feet above the proposed 14-foot plane, with an area of about 30 square yards in that plane, requiring the removal of about 12 cubic yards of ledge.

c. At the point marked H, where there are several small bowlders, or bowlder-shaped outcroppings, covering an area of about 16 square yards, the highest of which are 2¾ feet above the proposed 14-foot plane, and are estimated to contain about 8 cubic yards, in addition to which it will be necessary to remove about 8 cubic yards of sand and shells lying among the bowlders in order to obtain 14 feet of water over this area.

d. At the points marked K, I, L near the point H, the most salient part of the shoal, are outcroppings of the ledge having respectively 17¼ feet, 16½ feet, and 16¼ feet of water over them at mean low-water. Owing to the greater proximity of these rocks to the main ship-channel it would be advisable to remove them to a depth of 18 feet below the plane of mean low-water, requiring the removal of only about 5 cubic yards of ledge.

e. At the point marked D, near the line connecting buoys Nos. 8 and 10, is another outcropping of the ledge, the shoalest of all having over its highest point but 8 feet of water at mean low-water, requiring the removal of about 25 cubic yards of ledge in order to obtain a depth of 13 feet, which is here deemed sufficient below mean low-water.

To effect the improvement proposed as above will require altogether the removal of about 62 cubic yards of rock, the cost of which, at $25 per cubic yard, would be $1,550.

The removal of these rocks, with a more suitable placing of buoys Nos. 8 and 10, would greatly improve the navigation of this part of the harbor.

It is contemplated to have these rocks removed during the coming fiscal year under the appropriation made by act of June 23, 1874, for the improvement of this harbor.*

13. *Surveys of sunken rocks.*—The discovery in September, 1872, of an unknown rock in the main ship-channel at the Narrows, in the vicinity of Lower Corwin and Kelly's Rocks, created a doubt as to the existence of other unknown rocks in that vicinity.

*A contract was made for this work August 31, 1874, with Mr. William H. Lloyd, of Boston, Mass., who was the lowest of two bidders therefor, at $1,500, to be completed on or before June 30, 1875.

In July, 1873, a careful examination of this channel was made by dragging for several days between Corwin Rock and the northwest point of George's Island, and by taking a large number of range and random soundings east of Kelly's Rock, but without discovering any new rocks having less than 23 feet of water over them at mean low-water.

A similar examination has also been made over the shoals east of Great and Little Fawn, in Broad Sound, in order to ascertain the locality of certain dangerous rocks, the existence of which has been reported; but after a careful and extended search over an area of 1,000 by 500 feet, which was found to be covered with numerous bowlders of various sizes, no rocks were found having less than 13 feet of water over them at mean low-water.

The navigation of the north channel is almost always dangerous, and is especially so at low-water.

To remove all the rocks that would be necessary, should the improvement of the navigation of this place be undertaken, would cost much more than would be warranted by the benefit thereby gained.

In connection with the foregoing surveys, observations have been made at Lovell's Island, during the past season, on the rise and fall of the tides during a period of three lunations, and the plane of mean low-water, as determined thereby, has been marked by permanent benches for future reference in the improvements to be made in that part of the harbor.

Similar observations were also taken during the months of August, September, and October, 1873, at the wharf of Fort Independence, on Castle Island, preparatory to a continuance of the dredging at the upper middle-bar.

In the work heretofore projected for the preservation and improvement of Boston Harbor the attention of the Department has not been called to the condition of the low land near the southern extremity of Long Island, and its bearing upon the preservation of Sculpin-Ledge Channel. During the extraordinary gale of the 7–11th of October, 1873, this low land was overflowed and so washed out as to create serious apprehensions as to the danger that might ensue to that channel. A survey was at once made of this locality, in order to determine its condition and to ascertain what changes, if any, had taken place since the survey of 1860, as well as the cause of those changes. This survey showed that both the eastern and western shore-crests of the low neck of land which connects the south head with the main part of Long Island had been considerably weakened, in width as well as in height, since 1860, but that the main portion of the low land did not appear to have changed since then in character or level; also, that Sculpin-Ledge Channel had been somewhat encroached upon, the 12-foot curve being about 60 feet farther from the shore than in 1860.

It moreover appeared, on investigation, that all the damage done to those crests was caused by the removal, for sale, of a very large quantity of stone ballast, shingle, gravel, and sand from the shores, by the owner of the land, with the permission of the municipal authorities of Boston, from 10,000 to 12,000 tons of gravel having been removed to *one* wharf in Boston between the 1st of June and September, 1873.

In order to prevent, as far as practicable, with a small outlay, any further immediate damage to those crests, their lowest and weakest portions were raised and strengthened throughout, so as to have a height of not less than 2½ feet above the plane of mean high-water.

But afterward another gale, of still greater violence, occurred on the 16th and 18th of November, whereby this low land was again overflowed, the tide itself having risen higher than most parts of the shore-crests. None of the gaps of the crests, which were closed a few days previously, were opened by this storm; but close to, and south of what was formerly the most northern gully and the crests of the western shore, another wider, if not deeper, depression was made, through which the tide will enter at nearly every high-water; besides which the shore-crests, for an extent of two or three hundred feet, were lowered about one foot.

The attention of the city government of Boston has been called to this matter, and it is hoped that such action will be taken by it as may be necessary for the protection and preservation of this channel.

The following is a recapitulation of the estimated cost of the several works projected for the further improvement of Boston Harbor, viz:

1. Completion of sea-wall on north head of Long Island, under existing contracts, not including retained percentage			$2,041 66
2. Straightening, widening, and deepening the main ship-channel at "The Narrows"			56,000 00
3. Completing the channel through the upper middle-bar:			
a. 66,500 cubic yards dredging, at 64 cents, (as per contract of March 5, 1874,) not including retained percentage to July 1, 1874	$42 560 00		
b. 50,000 cubic yards dredging, at 85 cents (as per contract of September 1, 1874)	42,500 00		
c. 105,000 cubic yards additional dredging, at 85 cents	89,250 00		
			174,310 00
4. Removal of Nash's Rock			5,000 00
5. Completing the removal of Kelly's Rock			5,000 00
6. Removal of sunken ledge in "The Narrows"			500 00
7. Removal of State and Palmyra Rocks			1,550 00
Adding for engineering expenses and other contingencies, say			27,309 04
Total			271,710 70
Amount available July 1, 1874			151,710 70
Additional amount required for completing the projected improvement			$120,000 00

The several works built and projected for the improvement of this harbor lie within the port of Boston, and in the collection-district of Boston and Charlestown, Mass.

The amount of imports into this port for the fiscal year ending June 30, 1874, as furnished by the United States collector of customs, was $52,212,405; and the amount of duties received was $16,505,437 50. During the same period about 10,000 vessels of an estimated capacity of about 2,500,000 tons arrived and sailed from Boston Harbor.

The following papers are hereto appended, viz:

Abstract of proposals received, with names of bidders, (marked A.)
Abstract of contracts, with names of contractors, (marked B.)

Financial statement.

Balance in Treasury of United States July 1, 1873	$151,442 15
Amount in hands of officer and subject to his check	4,321 90
Amount appropriated by act approved June 23, 1874	100,000 00
Amount expended during the fiscal year ending June 30, 1874	93,041 46
Amount available July 1, 1874	151,710 70
Amount required for the fiscal year ending June 30, 1876	120,000 00

A.—*Abstract of proposals received February 26, 1874, for dredging 75,000 cubic yards, more or less, on the upper middle-bar, Boston Harbor, Massachusetts.*

No. for reference.	Names of bidders.	Residence.	Dredging, per cubic yard.	Rock excavation, per cubic yard.
1	Atlantic Dredging Company	Brooklyn, N. Y	$0 64	$35
2	Curtis, Fobes & Co	Portland, Me	69½	4[illegible]
3	T. H. Crosley	Boston, Mass	74	40
4	Morris & Cumings Dredging Co	New York City	90	35

B.—*Abstract of contracts made for the improvement of Boston Harbor, Massachusetts.*

Date of contract.	Contractor's name and residence.	Nature of work.	Price per cubic yard.	Remarks.
1874. March 5.	Atlantic Dredging Co., of Brooklyn, N. Y.	Dredging upper middle-bar...	$0 64	As measured in the scows.
		Removal of ledge and bowlders, if required.	35 00	

Y 17.

IMPROVEMENT OF DUXBURY HARBOR, MASSACHUSETTS.

The following appropriations have been made for the improvement of this harbor:

By act of Congress approved June 10, 1872	$10,000
By act of Congress approved March 3, 1873	10,000
Total	20,000

Under these appropriations contracts were made November 7, 1872, with Mr. Augustus R. Wright, of Geneva, N. Y., for 17,000 cubic yards, more or less, of dredging, at 50 cents per cubic yard; and May 6, 1873, with Mr. Hugh Cummiskey, of Boston, Mass., for 18,000 cubic yards, more or less, of dredging, at 49 cents per cubic yard, in the south channel of this harbor.

This channel extends from the "Cow-Yard," so called, up in a northwesterly direction between Captain's Hill and Kingston Flats for a distance of about three miles. For a distance of two and one-half miles it has a width of not less than 200 feet, with about 11½ feet of water at mean low-water, (or about 21 feet at mean high-water,) and for the remaining distance the channel is narrow and crooked, having a width of not more than 80 feet for a depth of 8 feet at mean low-water.

The improvement projected for this harbor consists in straightening and widening the upper portion of the channel, so as to have a width of 150 feet, for a depth of 8 feet at mean low-water, requiring about 35,000 cubic yards of dredging, for which the contracts were made.

Up to the 1st of July, 1873, 2,638 cubic yards had been dredged by Mr. Cummiskey, under his contract of May 6, 1873. This work was continued by him until the 22d of August, when he completed his contract

by the additional dredging of 16,360$\frac{3}{10}$ cubic yards, making a total of 18,998$\frac{3}{10}$ cubic yards.

Operations were commenced in September under Mr. Wright's contract, and were continued until the 3d of December, 1873, when they were suspended until the middle of May, 1874, at which time they were resumed and continued until completion, on the 30th of May, 1874, 15,660$\frac{7}{100}$ cubic yards having been dredged by him under his contract of November 7, 1872.

This completes all the work contemplated for the improvement of Duxbury Harbor.

Financial statement.

Balance in Treasury of United States July 1, 1873	$11,976 00
Amount in hands of officer and subject to his check, (including $258.52 percentage due on contracts not yet completed)	6,663 54
Amount expended during the fiscal year ending June 30, 1874	18,639 54

Y 18.

IMPROVEMENT OF PLYMOUTH HARBOR, MASSACHUSETTS.

The work projected for the improvement of this harbor, consists in the construction and repair of bulk-heads, jetties, and groins, built for the protection and preservation of Long Beach, which serves as a breakwater, and affords to the harbor inside the only shelter it has from easterly storms.

These bulk-heads and jetties are built either of stone, or else of cribwork and brush ballasted with stone; and the groins of small stones, with and without brush, intermixed.

The following appropriations have been made by Congress for this work, viz:

By act approved July 11, 1870	$10,000 00
By act approved March 3, 1871	10,000 00
By act approved June 10, 1872	2,500 00
By act approved March 3, 1873	3,000 00
By act approved June 23, 1874	5,000 00
Total	30,500 00
Amount available July 1, 1873	4,288 85
Amount expended during the fiscal year ending June 30, 1874	4,237 93

The work for the preservation and improvement of this harbor was resumed on the 1st of August, 1873, and continued until the latter part of November, when it was suspended until about the 1st of May following, and continued until near the end of the fiscal year.

During this period the work done was as follows, viz:

Twenty-three groins of brush and stone, having a total length of about 3,000 feet, and 10 groins of brush alone, having a total length of 534 feet, were constructed on the outer extremity of Long Beach. The brush and stone groins were made by placing brush flat on the surface of the beach and piling upon it beach bowlders to a height of about 18 inches. These groins are about 5 feet wide. The brush groins were made by digging a trench 2 feet by 2 feet, and placing brush in it upright and as close as practicable, the brush being held by sand being thrown into the trench and well rammed down, and sometimes further protected by small bowlders placed in a row along the sides of the groin. The brush rises about 2 or 3 feet above the surface of the beach. These groins are located as follows: Eleven brush and stone groins and three brush groins on the outside of the breakwater, perpendicular to it, and in the first 800 feet from the beacon; ten brush and stone groins and six brush groins on the outside of the plank bulk-head, perpendicular to it, and along a distance of 300 feet, commencing at a point about 1,800 feet from the beacon; one brush and stone groin at the beacon, on the inside of the bulk-head,

and perpendicular to it; one on the inside of and nearly parallel to the plank bulk-head, about 500 feet long, commencing about 400 feet from the beacon; and one brush groin fills an interval in the plank bulk-head about 1,700 feet from the beacon. In constructing these groins 1,583 tons of small bowlders were used.

In addition to this, over 10,000 hills of beach-grass have been planted, and repairs have been made where necessary upon the bulk-head and jetties on Long Beach.

Amount available for additional work July 1, 1874 ..... $5,050 92

This amount is to be applied to building additional brush and stone groins outside and inside the main bulk-head, and to the repairs of the brush bulk-head and jetties and the planting of beach-grass where most necessary.

For the further improvement and preservation of this harbor the following sums will be required, viz:

1. For completing the work projected for the preservation of Long Beach, and for such repairs, planting of beach-grass, &c., as may be necessary..	$2,000
2. Should it be decided to improve the harbor by dredging, as described in my special report to the Department, dated February 14, 1874, (a copy of which is hereto appended,) it is therein estimated that the cost thereof will be.....	28,000
Total.....	30,000

Financial statement.

Balance in Treasury of United States July 1, 1873..	$3,000 00
Amount in hands of officer and subject to his check.....	1,288 85
Amount appropriated by act approved June 23, 1874.....	5,000 00
Amount expended during the fiscal year ending June 30, 1874	3,860 90
Amount available July 1, 1874.....	5,427 92
Amount required for the fiscal year ending June 30, 1876	30,000 00

Y 19.

IMPROVEMENT OF WELLFLEET HARBOR, MASSACHUSETTS.

By an act of Congress approved June 10, 1872, the sum of $5,000 was appropriated for the removal of *rocks* at entrance of this harbor, and a contract was made August 23, 1872, with Mr. Samuel Dyer, of Truro, Mass., the lowest bidder, for the removal of the following-named sunken rocks, which had been found by a special survey to be the most dangerous obstacles to navigation, viz:

1. *Channel Rock*, situated about 2,000 yards to the southeast of Billingsgate light, and lying in about 12½ feet of water, with only 2 feet of water over it at mean low-water.

2. *Lobster Rock*, situated in mid-channel, about 1,400 yards to the eastward of Billingsgate light, and lying in about 18 feet of water at mean low-water, with only 4½ feet of water over it at mean low-water.

3. *Lumpfish Rock*, situated about 500 yards to the northeast of Lobster Rock, with 3½ feet of water over it at mean low-water.

4. *Mayo's Rock*, situated in mid-channel, 40 feet west of Buoy No. 7, and lying in 8 feet of water, with 2.7 feet of water over it at mean low-water.

5. *Bay Rock*, situated about 700 yards to the northwest of Mayo's Rock, and lying in 6 feet of water, and awash at mean low-water.

On the 14th of May, 1873, work, which had been suspended during the winter, was resumed upon the removal of these rocks, and up to the 1st of July, 1873, the following had been done, viz:

1. Channel Rock, completed.
2. Mayo's Rock, completed.
3. Bay Rock, nearly completed.
4. Lobster Rock, commenced.
5. Lumpfish Rock, commenced.

These operations were continued up to the latter part of July, when the removal of all the rocks contracted for was completed.

In addition to which other sunken rocks, not provided for by the contract, were removed by hired labor—one lying about 70 feet from Channel Rock and nearer the mid-channel, and others near Bay Rock—altogether, about 50 cubic yards.

Balance of appropriation available July 1, 1873	$4,179 69
Amount expended since July 1, 1873	4,179 69

Whereby all the work projected under the appropriation of June 10, 1872, has been satisfactorily completed.

Financial statement.

Amount in hands of officer and subject to his check	$4,179 69
Amount expended during the fiscal year ending June 30, 1874	4,179 69

Y 20.

IMPROVEMENT OF PROVINCETOWN HARBOR, MASSACHUSETTS.

Under the several appropriations heretofore made for the preservation and improvement of this harbor, the following work had been done on the 1st of July, 1873, viz:

1. Bulk-heads and jetties of various descriptions had been built from time to time along Beach Point for its preservation and protection, both by the United States Government and by the local authorities.
2. A dike was built in 1868 and 1869 by the State of Massachusetts across the outlet of East Harbor Creek.
3. A dike was built in 1868 and 1869 by the United States Government across East Harbor Creek, at the Wading Place, near High Head, about two miles above the outlet of the creek.
4. Wooden bulk-heads and jetties had been built at different times for the protection and preservation of the beach on Long Point.
5. A stone bulk-head had been commenced for the protection and preservation of the outer end of Long Point, opposite the light-house and the Three-Gun Battery.
6. A substantial dike (272 feet in length) was built in 1871–'72 across the head of Lancey's Harbor, near Abel Hill.
7. Beach-grass planted on Beach Point, Long Point, Abel Hill, Cove Section, and Oblique Section, and at the last two places brush had also been laid for their further protection.
8. The projected extension of the several jetties on Beach Point and State Dike had been nearly completed; and
9. Accurate resurveys had been made (1871, 1872, and 1873) of Cove Section, Oblique Section, Beach Point, and Long Point, together with elaborate soundings and current observations in the inner harbor.

Amount available July 1, 1873, for the continued preservation of this work was $2,386.62.

In the month of July, 1873, work was prosecuted with hired labor upon the projected extension of the jetties on Beach Point, and on the 1st of August it was suspended until the 1st of December, 1873, when it was again resumed and continued until the 1st of May, 1874, and then again suspended until the latter part of July, 1874.

The work done during the year has been applied as follows, viz:

1. To the completion of all the jetties on Beach Point and State Dike to the extent projected, and of brush and stone groins connecting the outer ends of the jetties.
2. To the repair of the bulk-head and jetties on Beach Point and State Dike, and beach-grass planted where most necessary.
3. To rebuilding and strengthening the outer end of the stone bulk-head on Long Point; and
4. To building at Cove Section a bulk-head of timber and brush, ballasted with stone, 190 feet long, rendered necessary for the protection and preservation of the beach at that place, from the fact that, by the extraordinary gale of November 16, 1873, the crest-line of the shore, for an extent of about 200 feet, had been carried 30 feet inward and lowered about 3 feet, so as to have a height of only about 10 feet above the plane of ordinary high-water. This bulk-head was completed about the middle of January, 1874, when, owing to another very unusual storm, the beach was still further encroached upon, so as to make it advisable to remove the bulk-head further inward, where it would require a total length of about 590 feet, for the reasons stated in my special report to the Department dated January 21, 1874. For want of sufficient funds, this work was not undertaken at that time.

On the 1st of July, 1874, there was available for the improvement of this harbor (including $6,000 appropriated by act of June 23, 1874) the sum of $6,103.48, which it has been decided to have applied as follows, viz:

1. Repairs of bulk-head and jetties and building of short brush and stone groins on Beach Point.
2. Extending and strengthening stone bulk-head for the protection and preservation of Long Point, in front of the light-house and Three-Gun Battery.
3. Building a brush bulk-head and jetties for the preservation of the beach at Cove Section, on the outer beach. The materials for all the projected work to be purchased in open market and the work to be done with hired labor.

For continuing the works required for the preservation of this harbor, the additional sum of $5,000 will be required for the fiscal year ending June 30, 1876, for the following purposes, viz:

1. Repairs of bulk-head and jetties on Beach Point and State Dike	$700
2. Repairing dike at Wading Place, near High Head	200
3. Extending and raising stone bulk-head for the protection and preservation of Long Point, near the light-house and Three-Gun Battery	1,500
4. Additional work on dike at Lancey's Harbor	50
5. Planting beach-grass for the preservation and strengthening of outer beach	700
6. Resurvey of outer beach, Long Point, Beach Point, &c	400
Adding for contingencies, say	1,450
Total	5,000

Provincetown is a port of entry within the collection-district of Barnstable.

The amount of revenue received at this port during the fiscal year ending June 30, 1874, was $1,312.80.

The number of vessels engaged in coasting trade and foreign trade which have resorted to this harbor for refuge and trade during the past year, (as stated by the deputy collector at that port,) from the best available information, is estimated to be not less than 8,500 sail.

Financial statement.

Balance in Treasury of United States July 1, 1873	$3,000 00
Amount appropriated by act approved June 23, 1874	6,000 00
Amount expended during the fiscal year ending June 30, 1874	2,283 14
Amount available July 1, 1874	6,103 48
Amount required for the fiscal year ending June 30, 1876	5,000 00

Y 21.

SURVEY OF AROOSTOOK RIVER, MAINE.

UNITED STATES ENGINEER OFFICE,
Portland, Me., December 13, 1873.

GENERAL: I have the honor to submit the following report on the survey of Aroostook River, Maine.

This survey was called for by act of Congress approved March 3, 1873, "making appropriations for the repair, preservation, and completion of certain public works on rivers and harbors, and for other purposes," and was made in August last by Mr. Sophus Haagensen, assistant engineer, under my instructions. His report on the same, prepared under my direction, is also herewith submitted.

This survey, which was made for the purpose of ascertaining the practicability of improving the navigation of this river, embraced an extent of sixty-nine miles, commencing at the international boundary near the "falls," (about four miles above its junction with the river St. John, in the province of New Brunswick,) and extending upward to the mouth of the St. Croix or Masardis Stream. This river is navigable, in its present condition, only for about three months of the year, even for boats drawing but 2 feet of water, its navigation being obstructed for the remaining part of the year, when not closed with ice, by a great number of shoals or bars extending across the river, with a depth, during the low stages of summer, varying from 4 inches to 2 feet over their deepest parts. These occur at about ninety places, and generally consist of coarse gravel or shingle intermixed with loose bowlders or rocks, varying in weight up to seventy tons.

In order to obtain sufficient water over these bars to make the river navigable in its lowest stages for boats drawing 2 feet of water, it will be necessary to excavate those bars and remove the rocks to the requisite depth, or else, where the river widens or is divided by islands into several channels, to build wing-dams, which will throw the water over the deepest part of the bar or close up the side channels.

The estimated cost of this work, as shown in the accompanying statement, is $50,000, being for making a channel 50 feet in width and 2 feet in depth in the lowest stages of the river, from the international boundary-line up to Masardis, a distance of sixty-nine miles.

The extent to which the commerce of the country would be promoted by this work would probably be limited, as for several months of the year the river is closed with ice; and as, moreover, the continuity of water-transportation would be, as it now is, broken by the "falls," which are in the province of New Brunswick, about one mile below the international boundary. Under these circumstances, it is more than probable that the commerce on the river would continue to be merely local. Besides, the right of navigating this river, it is understood, has been conferred by an act of legislature of the State of Maine upon a private company, which would probably have the exclusive control over it, even if improved at the expense of the United States Government.

Respectfully submitted.

GEO. THOM,
Lieut. Col. of Engineers, Bvt. Brig. Gen., U. S. A.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

Report of Mr. Sophus Haagensen, Assistant Engineer.

UNITED STATES ENGINEER OFFICE,
Portland, Me., December 9, 1873.

GENERAL: I have the honor to report upon the examination of Aroostook River from the "falls" near the international boundary-line to the junction of Aroostook River and the St. Croix or Masardis Stream, in the town of Masardis, made in pursuance of your letter of instruction of July 23, 1873.

I left Calais, Me., July 31; arrived in Presque Isle August 1, and after completing the examination, returned to Calais, August 12.

The sources of Aroostook River are in Piscataquis and Northern Penobscot Counties; soon after entering Aroostook County these streams unite and form the Aroostook River in township 9, range 8, about latitude 46° 15′, longitude 69°. From thence it flows in a northeasterly direction through township 9, range 7, 9, range 6, or Oxbow Plantation, 10, range 6, Masardis, Ashland, Buchanan, Castle Hill, Wade Plantation, Washburn, Mapleton, Maysville, Lyndon, Forestville, and Fort Fairfield, all in Aroostook County. At Fort Fairfield, on the international boundary-line, it enters New Brunswick; here are the Aroostook Falls, and four miles below the river flows into river St. John near Tobique village.

The principal tributaries to Aroostook River are: On the north side, Big Machias, Little Machias, Beaver Brook, Salmon Stream, Caribou Stream, and Little Madawaska. The Limestone Stream joins the Aroostook below the "falls" in New Brunswick. On the south side are: Umcolcus Stream, Masardis or St. Croix Stream, Squawpan Stream, Alder Brook, and Presque Isle Stream, besides a great many smaller streams. The Aroostook River and its tributaries water about fifty townships, or nearly eighteen hundred square miles.

The length of the Aroostook River from township 9, range 8, to its confluence with the river St. John, is ninety-six miles; the last four miles are beyond the international boundary-line.

The farthest settlements on the river are in Oxbow Plantation, a distance of eighty-three miles from the boundary-line, but the most important part of the river which at present is navigated is from the junction of Aroostook with the St. Croix Stream in Masardis, a distance of sixty-nine miles by the river-channel to the boundary-line, the part of the river embraced in the called-for examination.

The navigation of this river is at present limited to a very short time of the year, owing to the numerous obstructions in the river at its low-water stage. The contemplated improvement would consist in the removal of these obstructions, so as to enable small steamboats of about 50 tons burden and not over 2 feet draught to navigate the river, carrying merchandise and passengers and towing lumber.

An unobstructed channel, with not less than 2 feet depth at the lowest summer water-level, and a width of at least 50 feet, will be required for that purpose, and for this channel the following estimates have been made.

The stage of the river when the examination was made was the lowest water observed during the last eight summers, and 1 foot below mean summer level; consequently favorable for observing and examining the various obstructions. Last year's (1872) summer water-level was very high, almost 2 feet higher than this summer. The summer water-level varies thus 1 foot above or below mean summer level.

The average level of the river at spring high-water is 10 feet above mean summer water-level. Last spring, which was the highest water observed for a long period, the river was 14 feet higher than when the examination was made, or 13 feet above mean summer water-level.

At present there will only be water enough during three months of the year to enable boats of 2 feet draught to navigate the river; with an improved channel, as that contemplated, navigation would be extended to six months of the year.

The river is settled along the whole line of proposed improvements on both sides; saw and shingle mills are worked by its numerous tributaries; the lumber business is already extensive. Without data the business cannot be computed, but it is believed that two or more boats would have constant employment, to the great development and advantage of the country. Goods now brought from Boston to the towns up the river, Ashland, Masardis, &c., are shipped to Calais; thence carried by rail to Houlton, and from there hauled by teams a distance of about seventy miles; the cost per ton of freight is $45 to $50, whereas if the contemplated improvements are made freight could be brought from Boston via St. John River to Tobique for $12 per ton; hauled round the "falls" from Tobique to Fort Fairfield for $1 per ton; and transported on the river steamboat for $5 per ton, and *vice versa;* in all, $18 per ton, a reduction in rates of transportation of 60 per centum.

* * * * * * *

Iron-ore is abundant along the river in Wade Plantation and Washburn; works will soon be started, and the further development of this industry will be proportionate to cheap rates of freight.

The nature of the existing obstructions are shoals or bars extending across the river, with a depth of water varying from 4 inches to 2 feet over the deepest part; they are all of the same description, consisting of coarse gravel or shingle; between these bars are reaches with water from 4 to 10 feet deep, often with an unobstructed channel, but frequently obstructed by loose bowlders or rocks, varying in size from a few tons to 70 tons.

To obtain sufficient water over these bars, viz, 2 feet at the lowest stage of the river, it will either be necessary to excavate a channel through the bar, or, where the river widens or is divided in several channels by islands, to build wing-dams, which shall throw the water over the deepest part of the bar, or close up side channels. The top of the dam is proposed to be 1½ feet above lowest summer water-level. When the river rises to this level, there will be sufficent water over the bars and cuts, and the wing-dam will allow the water to pass over it at this stage. It is proposed to build these dams of large bowlders, which are found in abundance near most of the bars, and the cost per running foot of the dam is estimated at from $3 to $4.

The excavation of a channel through the various bars could be done best by an iron scraper, drawn by oxen or horses, and the cost of removal of material is estimated at $1 per cubic yard.

The removal of rocks obstructing the channel would be done by hauling the rocks out of the channel to the river-banks, in case the rocks are not too heavy to be started from their bed by horses and tackle; a great many would have to be drilled and blasted; and where the water is not deep enough to allow the fragments to remain where they fall, these will have to be hauled out of the channel.

On Davenport Ledge (obstruction No. 86) a crib-work fender-pier would have to be built, the current setting right against the shore at this point.

The accompanying table gives the name of the various obstructions, in the order they are met with in going down the river, from Masardis to the boundary-line. In the third and fourth columns the locality of each obstruction is given; the township in which they are found in the third column; the distance from the boundary-line to the obstruction in the fourth; the nature of the proposed work to be done at each place is found in columns five to eleven, inclusive, as well as the separate cost of removing gravel, (column 6;) rock that can be moved without drilling and blasting, (column 7;) rock which must be broken up before removing, (column 8;) the number of wing-dams to be built, (column 9;) their aggregate length at each obstruction, (column 10;) and their estimated cost, (column 11.) In column 12 the aggregate cost of the various work to be done at each place is found.

The total cost of the proposed improvements for procuring a navigable channel 50 feet wide, with not less than 2 feet of water in it at the lowest stages of the river, from the international boundary-line up to Masardis, where the St. Croix or Masardis Stream flows into the Aroostook River, the whole length of said channel being sixty-nine miles, is estimated at $50,000, viz:

Cost of excavating channels in the gravel-bars	$21,355
Cost of removing loose rocks	5,875
Cost of building wing-dams	17,100
Cost of fender-pier on Davenport Ledge	500
	44,830
Contingences, say	5,170
Total	50,000

This estimate is made under the supposition that the work is done when the river is at its ordinary summer level; a higher water will increase the cost of the work, especially the removal of rocks.

An outlay of from $6,000 to $8,000 would greatly benefit the navigation of the river; this amount would be sufficient for clearing a 50-foot channel, throughout its entire length, of dangerous rocks, and enable steamboats of 2 feet draught to pass from the Aroostook Falls to Masardis at stages of the river when there is 2 feet of water over the shoalest of its bars.

Very respectfully, your obedient servant,

SOPHUS HAAGENSEN,
Assistant Engineer.

Bvt. Brig. Gen. GEO. THOM,
Lieut. Col. Corps of Engineers.

Table showing obstructions to navigation in Aroostook River, Maine, their locality, the nature of proposed work, and the estimated cost of removing these obstructions, so as to procure a navigable channel of not less than 50 feet in width, and not less than 2 feet of water in it at the lowest summer water-level.

No. of obstructions.	Name of obstruction.	Locality—township.	Distance in miles from the boundary-line.	Proposed improvements.							Amount.
				Excavation of gravel.		Removal of rock.		Building of wing dams.			
				No. of cubic yards.	Cost.	By hauling, at cost of—	By drilling and blasting, at cost of—	No.	Length in running feet.	Cost.	
1	Gordone Bar	Masardis	69	.....	.....	$150	.....	.....	.....	.....	$150
2	Leavitt's Bar	do	68½	.....	.....	.....	.....	1	200	$700	700
3	Copperthwait Bar	do	68	.....	.....	100	$20	.....	.....	.....	120
4	Noble's Rapids	do	66¾	150	$150	.....	.....	.....	.....	.....	150
5	Dean's Rapids	do	66½	420	420	.....	.....	.....	.....	.....	420
6	Rocks at Trafton Island	do	66	.....	.....	.....	50	.....	.....	.....	50
7	Trafton Bar	do	65	.....	.....	.....	.....	1	125	400	400
8	Rock at Trafton, Bush Island	do	64½	.....	.....	.....	20	.....	.....	.....	20
9	Big Machias Bar	Ashland	59	.....	.....	30	.....	.....	.....	.....	30
10	Rocks between Big Machias and Bearce's Bars.	do	58¾	.....	.....	80	20	.....	.....	.....	100
11	Bearce's Bar	do	58½	.....	.....	.....	.....	1	250	*250	250
12	Ashland Bridge Bar	do	58¼	.....	.....	100	.....	.....	.....	.....	100
13	Rocks below Ashland Bridge	do	57¾	.....	.....	60	.....	.....	.....	.....	60
14	Rocks at the mouth of Little Machias.	do	56¾	.....	.....	.....	50	.....	.....	.....	50
15	Rocks between Little Machias and Bigger's Bar.	do	56½	.....	.....	40	.....	.....	.....	.....	40
16	Rocks between Bigger's and Porter's Bars.	do	56¼	.....	.....	80	.....	.....	.....	.....	80
17	Porter's Bar	Buchanan	56¼	600	600	.....	.....	.....	.....	.....	600
18	Capsooglet Rocks	do	56	.....	.....	60	140	.....	.....	.....	200
19	Flint Rocks	do	55¾	.....	.....	50	50	.....	.....	.....	100
20	Walker Landing Rocks	do	55¼	.....	.....	.....	75	.....	.....	.....	75
21	Walker Landing Bar	do	54¾	1,100	1,100	.....	.....	.....	.....	.....	1,100
22	Berry Landing Bar	do	54¼	.....	.....	140	20	.....	.....	.....	160
23	Alder Brook Bar	do	54	.....	.....	60	.....	.....	.....	.....	60
24	Goss Rock, upper bar	do	53¾	.....	.....	30	.....	.....	.....	.....	30
25	Goss Rock, lower bar	do	53½	.....	.....	30	.....	.....	.....	.....	30
26	Burntland Island Rocks	do	52¾	.....	.....	100	100	.....	.....	.....	200
27	Allen's Landing Rocks	do	51	.....	.....	50	.....	.....	.....	.....	50
28	Pudding Rock Bar	do	50¾	.....	.....	200	.....	.....	.....	.....	200
29	Pudding Rock, lower island	do	50½	.....	.....	30	.....	.....	.....	.....	30
30	Grindstone Ledge, upper bar	do	50	1,000	1,000	50	.....	.....	.....	.....	1,050
31	Grindstone Ledge, lower bar	do	49¾	.....	.....	100	.....	.....	.....	.....	100
32	Beaver Brook Bar, No. I	do	49	.....	.....	150	.....	.....	.....	.....	150
33	Beaver Brook Bar, No. II	do	48¾	280	280	60	40	.....	.....	.....	380
34	Beaver Brook Bar, No. III	do	48½	.....	.....	40	.....	.....	.....	.....	40
35	Beaver Brook Bar, No. IV	do	48¼	420	420	.....	.....	.....	.....	.....	420
36	Beaver Brook Bar, No. V	Castle Hill	48¼	.....	.....	70	.....	.....	.....	.....	70
37	Beaver Brook Bar, No. VI	do	48	.....	.....	180	.....	2	400	1,400	1,580
38	Trask Lower Island Bar, No. I	do	46¼	.....	280	.....	.....	.....	.....	.....	280
39	Trask Lower Island Bar, No. II		46	840	840	.....	.....	.....	.....	.....	840
40	Bryant Island Bar		45¼	.....	.....	250	.....	.....	.....	.....	250
41	Rocks between Bryant Island Bar and Trask Landing.	Castle Hill	45	.....	.....	100	.....	.....	.....	.....	100
42	Rocks between Trask Landing and Mash's Island.	do	44¾	.....	.....	100	50	.....	.....	.....	150
43	Mash's Island, upper bar		44½	.....	.....	150	.....	.....	.....	.....	150
44	Mash's Island, lower bar	Wade Plantation.	44	.....	.....	150	.....	.....	.....	.....	150
45	Gardner Creek, upper bar	do	43	420	420	200	.....	.....	.....	.....	620
46	Gardner Creek, lower bar	do	42½	1,700	1,700	.....	.....	.....	.....	.....	1,700
47	Rocks off Randall's Ledge	do	42	.....	.....	.....	40	.....	.....	.....	40
48	Donelly's Upper Bar	do	42	.....	.....	100	.....	.....	.....	.....	100
49	Donelly's Lower Bar	do	41¼	200	200	50	.....	.....	.....	.....	250
50	Rocks between Donelly's Island and Iron-Ore Bars.	do	40¾	.....	.....	100	.....	.....	.....	.....	100
51	Iron-Ore Bars	do	40	2,700	2,700	.....	.....	1	100	350	3,050
52	Pelkey's Bar	Washburn.	39	830	830	.....	.....	.....	.....	.....	830
53	Stratton Island Bars	do	38¼	1,660	1,660	.....	.....	.....	.....	.....	1,660
54	Rocks off Brennan Island	do	37¾	.....	.....	60	.....	.....	.....	.....	60

* There is a great quantity of large bowlders on the flats.

Table showing obstructions to navigation in Aroostook River, Maine, &c.—Continued.

No. of obstructions.	Name of obstructions.	Locality—township.	Distance in miles from the boundary-line.	Proposed improvements.							Amount.
				Excavation of gravel.		Removal of rock.		Building of wing-dams.			
				No. of cubic yards.	Cost.	By hauling, at cost of—	By drilling and blasting, at cost of—	No.	Length in running feet.	Cost.	
	Easty's Island Rocks	Washburn.	37½	.....	.....	$20	.....	...	.....	.....	$20
	Thunder Island Bar	....do	36¼	285	$285	.....	.....	...	.....	.....	285
	Hickey's Bar	....do	36¼	700	700	.....	.....	...	.....	.....	700
	Rowse's Upper Bar	....do	35¾	560	560	.....	.....	...	.....	.....	560
	Rowse's Lower Bar	....do	35⅝	.....	.....	100	.....	...	.....	.....	100
	Crouse's Bar	....do	35	560	560	.....	.....	...	.....	.....	560
	Easler's Bar	....do	34	560	560	70	.....	...	.....	.....	630
	Rocks above Rum Rapids	....do	33	.....	.....	70	.....	...	.....	.....	70
	Rocks on Beckwith Bar	Maysville.	32½	.....	.....	50	.....	...	.....	.....	50
	Presque Isle Bar	....do	29	830	830	100	.....	1	200	$700	1,630
	Blake's Bar	....do	27½	.....	.....	30	.....	...	.....	.....	30
	Canada Bar	....do	26	600	600	80	.....	...	.....	.....	680
	Bean's Rapids	....do	25	.....	.....	120	.....	...	.....	.....	120
	Folsom Bar	....do	23	740	740	.....	.....	...	.....	.....	740
	Gray's Bar	....do	22	550	550	.....	.....	...	.....	.....	550
70	Hardwood Bar	....do	21	.....	.....	100	.....	...	.....	.....	100
71	Robert's Bar	Lyndon ...	20½	.....	.....	120	.....	...	.....	.....	120
72	McCubury's Upper Bar	....do	19½	550	550	100	.....	...	.....	.....	650
73	McCubury's Lower Bar	....do	19¼	.....	.....	20	.....	...	.....	.....	20
74	Hardison's Bar No. I	....do	18¾	.....	.....	30	.....	...	.....	.....	30
75	Hardison's Bar No. II	....do	18½	.....	.....	.....	.....	2	400	1,400	1,400
76	Hardison's Bar No. III	....do	18¼	280	280	.....	.....	...	.....	.....	280
77	Hardison's Bar No. IV	....do	18	280	280	.....	.....	...	.....	.....	280
78	Sand's Upper Bar	....do	17½	.....	.....	100	.....	...	.....	.....	100
79	Sand's Lower Bar	....do	17	.....	.....	.....	$50	...	.....	.....	50
80	Boobar's Bar	....do	16½	.....	.....	100	.....	1	400	1,400	1,500
81	Caribou Bars	....do	15	1,100	1,100	80	60	2	600	2,100	3,340
82	Cochrane Upper Bar	....do	14	.....	.....	60	.....	...	.....	.....	60
83	Cochrane Lower Bar	....do	14	.....	.....	60	.....	1	350	1,925	1,285
84	Otter Brook Rapids	Forestville.	13	.....	.....	60	.....	...	.....	.....	60
85	Doyle's Bar	Lyndon ...	10	740	740	.....	.....	...	.....	.....	740
86	Davenport Ledge	Fort Fairfield.	7	.....	.....	.....	.....	...	.....	.....	*500
87	Bishop Island	....do	5½	.....	.....	.....	.....	1	450	1,575	1,575
88	Boom Island	....do	4	.....	.....	.....	.....	2	800	2,800	2,800
89	Fort Fairfield Shoals	....do	3	.....	.....	250	.....	4	800	2,800	3,050
90	Nelson Bar	....do	2½	420	420	70	.....	...	.....	.....	490
											44,830
	Contingencies, say	.....	.....	.....	.....	.....	.....	...	.....	.....	5,170
	Total cost of improvement	.....	.....	.....	.....	.....	.....	...	.....	.....	50,000

* A fender-pier built of crib-work.

Y 22.

SURVEY OF PENOBSCOT RIVER, FROM OLDTOWN TO MEDWAY AND VICINITY, MAINE.

UNITED STATES ENGINEER OFFICE,
Portland, Me., December 13, 1873.

GENERAL: I have the honor to submit the following report on the survey of Penobscot River, from Oldtown to Medway and vicinity, Maine.

This survey was provided for by act of Congress approved March 3, 1873, "making appropriations for the repair, preservation, and com-

pletion of certain public works on rivers and harbors, and for other purposes," and was made under my instructions, in August last, by Capt. William S. Stanton, United States Corps of Engineers, whose report thereon is herewith submitted.

The object of this examination was to ascertain the practicability and cost of improving the navigation of this river between the limits specified (being a distance of about sixty-five miles) for small boats of not more than 2 feet draught, such as now run, at times, upon this river, so that they may be able to navigate it even in its lowest stages of summer.

You are respectfully referred to the accompanying report of Captain Stanton, which contains all the information in my possession upon this subject. His estimate for such work as would be required to render the river navigable to the extent proposed is as follows, viz:

I. For cutting a channel, 75 feet wide and 3 feet deep, through the obstructions between Oldtown and Winn, Me	$122,018 00
II. For a channel, 60 feet wide, 2½ feet deep, between Winn and Medway	53,310 00
III. For a channel, 60 feet wide, 2½ feet deep, between Medway and Rocky Rips, on the East Branch	33,200 00
	208,528 00
Adding for contingencies and engineering expenses, say 15 per cent	31,279 00
Total	239,807 00

or, say, $240,000.

The extent to which the commerce of the country would be promoted by this work, as shown by Captain Stanton, is very limited, in comparison with the expense that would attend it.

Attention is also asked to the fact that this part of the river is separated from tide-water by the impassable falls, having a descent of 92 feet, between Bangor and Oldtown, for a distance of twelve and a half miles; and to the fact that for several months of the year its navigation is interrupted by ice; also to the fact that it lies wholly within the State of Maine, and thereby offers advantages exclusively local in their character.

Respectfully submitted.

GEO. THOM,
Lieut. Col. of Engineers, Bvt. Brig. Gen., U. S. A.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

Report of Capt. W. S. Stanton, Corps of Engineers.

UNITED STATES ENGINEER OFFICE,
Boston, Mass., September 25, 1873.

COLONEL: By instructions conveyed in your letter of July 30, 1873, I was required to make an examination of the Penobscot River from Oldtown, Me., to Medway, Me., and vicinity, with a view to the improvement of its navigation, and in making it to give attention to the following points, viz:

1. "For what purpose it is desired to have the navigation of this portion of the river improved, and the depth of water required therefor;"

2. "What is the stage of water in the river at the present time, as compared with other seasons of the year; and for what period of the year can its navigation be made practicable?"

3. "The nature and extent of the commerce and navigation of this portion of the Penobscot River, and, as near as practicable, the extent to which the same would be benefited by improving the navigation;" and

4. "The nature, extent, and locality of the existing obstructions to its navigation, and probable cost of their removal, as well as the necessity therefor."

Pursuant to the foregoing, I repaired, after visiting Bangor and Oldtown to procure information and the necessary force and outfit, to Medway on Saturday, the 9th ultimo, commenced the examination on the 11th, finished it on the 16th ultimo, and now have the honor to submit the following report:

Navigation on the Penobscot River above Oldtown is absolutely separated from tide-water navigation extending to Bangor by the falls at Oldtown, and by the character of the river between the two places. At the Oldtown Falls the river-bed descends 20 feet in a horizontal distance of 100 feet, the water there plunging over falls and shooting down rapids on a rough bed of slate ledge extending across the river. From the crest of these falls to the head of tide-water at Bangor, a distance of twelve and one-half miles, the river-bed descends 92 feet. At intervals in this distance, where at places the bed is of slate-ledge, and at others of bowlders, the water is shallow and the current very rapid. It is, therefore, impracticable to make the navigation of that part of the river embraced in this examination continuous with tide-water navigation without the construction of a canal around the Oldtown Falls, at an expense which it is probable will continue many years; hence, uncalled for and utterly unjustifiable by the interests to be subserved.

Above Oldtown the obstructions consist of shoals of gravel and of rapids; the former vary in length from about 200 feet to about two-thirds of a mile, and the latter from about 500 feet to about one and one-quarter miles. While the shoals are obstructions only during the low stage, the rapids are more or less troublesome during all stages of the water. The most of them consist of large assemblages of bowlders, but some of ledges of rock and bowlders, extending across the river. Some contain comparatively few, others immense numbers of bowlders of all sizes up to 12 or 15 feet in diameter, resting on a bed of small bowlders or slate ledge, and thickly scattered about the river.

The channel is generally tortuous between the large bowlders or jutting points of ledge; the slope of the river-bed greatly increased; the current extremely rapid; and the water often rough and turbulent. Between Mattawamkeag and the crest of the Oldtown Falls, a distance of forty-five and one-half miles, the river-bed has a descent of 98 feet. In the channel the minimum depth of water is greater over the rapids than on the shoals.

Between the obstructions there are often long reaches entirely unobstructed, with a good gravel bottom, a smooth, gentle current, and a depth of water varying from 4 to 8 or 9, and occasionally reaching 10, 12, or 15 feet.

Between Oldtown and the confluence of its two branches at Medway, the river varies in width from about one hundred to about four hundred yards, and averages about three hundred yards. Its width is nowhere greatly increased during high-water, and its banks are not subject to overflow. It contains a rather large number of islands, sometimes dividing it into narrow chutes. Its water is clear.

Above Oldtown, excepting the large numbers of logs annually brought down, there is now no commerce of importance on the river.

From about 1850 to about 1870, two steamboats, drawing when loaded 2½ feet of water, plied daily between Oldtown and Winn, a distance of forty-three miles, each passing up or down on alternate days. The average quantity of freight carried each way daily was about 15 tons; domestic supplies, groceries, and provisions were carried up the river, and lumber, clapboards, and shingles brought down.

These boats were prevented from running by ice usually from about the 1st of December until about the 15th of April, and by the low stage of water generally from about the 1st of July until about the 1st of October. The river between Oldtown and Winn, it thus appears, is navigable for steamboats drawing 2½ feet of water only about four and one-half months annually, two and one-half during the spring and summer, and two months during the autumn. It could be made navigable for boats drawing 2½ feet of water throughout the year, when not obstructed by ice, between Oldtown and Rocky Ripe, a point on the East Branch about seven miles above Medway, but only at an expense, in proportion, far greater than the magnitude of the interests involved.

The European and North American Railroad, between Bangor and St. John, New Brunswick, crosses the river at Oldtown and runs forty-five miles along its left bank to Mattawamkeag, where it leaves the Penobscot, and runs northeasterly up the right bank of its tributary, the Mattawamkeag. When, in 1870 or 1871, this railroad was first put in operation, the two steamboats stopped running, and the only boats which have been on the river since that time are two small freight-steamboats, owned and used by the firm of Henry Poor & Son, of Boston.

Your letter of instructions referred to Mr. E. S. Poor, of that firm, "for much valuable information concerning the commerce and navigation of this river," and inclosed a copy of a letter of May 17, 1873, to yourself, from him, in which he says: "My interests in the improvements near the mouth of the river are only in common with the whole public of Bangor; but in the desired improvements in the upper part of the

river, from Winn and above, we (that is, the firm of Henry Poor & Son, to which I belong) have an especial interest. I should be pleased to show you where a moderate expense will be of immense advantage to the navigation of the river, and would like to be informed when you will propose to make the examination. * * * * * * *

"We have two boats running on the river, one from Mattawamkeag to Medway, the other to different places, as we may need her services. General Hersey, the member-elect to Congress from Bangor, is interested somewhat largely in lands above Medway, and his judgment as to the needs above Medway would be very good."

In a letter of August 2, 1873, to me, Mr. Poor also says: "As the order was passed through Congress principally at my suggestion, I have had a strong desire to be present when the survey was made, more especially between Winn and Medway, and in the vicinity of Medway. I have no desire to make any suggestions in relation to improvement of the river in the vicinity of Bangor, but would like very much to be with you when you will be engaged in the survey of the upper part of the river, say from Winn to Medway."

One of the two boats of this firm has a carrying capacity of about 15 tons, draws when thus loaded 23 inches of water, and is used by them for transportation between their tanneries at Medway and Winn, and for supplying those tanneries with bark from the banks of the east branch of the river; the other is somewhat larger, and is used by them to transport hides, leather, and tannery supplies between Oldtown and Winn; the quantity of freight which it carries is about 2½ tons daily.

The above very limited navigation and commerce carried on by this firm, exclusively in connection with their tanneries, is the entire extent of steamboat navigation now on the river above Oldtown, and of the commerce which it subserves.

From all the information I have obtained, the *purpose* for which it is desired to have the Government improve this part of the river is to benefit the very limited navigation thus carried on by this firm, by prolonging the time during which their boats can run annually. It is urged by them that the improvement of this part of the river would lead to the establishment of wooden-ware manufactories on its banks; would largely increase the commerce upon it, and greatly develop the region of country through which it flows. I do not think this increase in commerce or development would be either great or important, and cannot discover upon what it would be founded.

The soil, especially along the upper part of the river, is not very productive, and is of but little value for cultivation. The river, even if improved so as to be navigable for boats of light draught throughout the low-water season, would still be closed by ice about one half of the year. Above Oldtown the country bordering on the river is nowhere thickly settled. The seven townships above Winn, including it and that across the river, through which flow the Penobscot, and, for ten miles above their junction, its two branches, contain, by the census of 1870, a population of only 1,821. They are to a great extent wooded, but the greater part of the most valuable timber has been cut. Above Medway, which is merely a tannery settlement, the country is rugged and almost wholly a wilderness. Excepting about seven miles on the East Branch, just above their confluence, the two branches are too rocky to be made navigable. On their banks are large quantities of slate, apparently of good quality.

The important traffic on the river above tide-water consists entirely in the large numbers of logs annually floated down from its tributaries, its extreme head-waters and branches, and sawed into lumber at Oldtown and Bangor. During the past three years the following quantities of logs, expressed in feet, board-measure, have been brought down the river to these two places: In 1870, 202,014,194 feet; in 1871, 227,491,675 feet; and in 1872, 246,453,649 feet, of which the average annual value before manufacture, at $12 per 1,000 feet, is $2,735,757.11 Of the above quantity it is said that from fifteen to twenty million feet are annually brought down the Passadumkeag; from two to six millions down the Piscataquis; from sixty to seventy-five millions down the Mattawamkeag; from twenty to thirty millions down the East Branch; and the balance, from one hundred to one hundred and twenty million feet, down the West Branch. Some of the logs brought down the tributaries are rafted, but much the larger part of the above quantities are floated down without rafting, immense numbers together forming what are called "drives." The largest "drive," containing frequently from sixty to ninety million feet of logs, extending for miles along the river and requiring about two hundred men to attend it, usually starts on the West Branch in April and arrives at the booms above Oldtown in July. When during the descent of this "drive" the stage of water in the river becomes so low as to retard its advance, it is raised successively by opening ten or twelve gates in dams constructed at the Twin Lakes on the West Branch for that purpose. The running of logs in this manner is considerably obstructed by very numerous large bowlders in the river, and *especially* in its West Branch. The tallest of these bowlders catch a log or two, against which others rapidly accumulate, and form large "jams," which stop a "drive," and which consume much labor before it can be released. The large "drive," it is said, is sometimes stopped in this way two days, at a loss in the pay of its men, at an average rate of $3 per day, of

$600 per day, caused by a few bad bowlders which might be rendered harmless by the expenditure of a trifling sum in blasting off their tops during the low-water stage. It is asserted by men familiar with the running of logs that an expenditure of $50,000 would result in saving to the lumber interest $10,000 annually. Excepting the construction of a dam at the "Five Islands," to prevent logs from gathering and lodging in two narrow chutes, the main improvement desired by this interest consists in reducing the heights of very numerous bowlders to about 2 or 3 feet above the surface of the water at the low-water stage. To do this by blasting, the fragments being left where they fall, would cost say from $5 to $10 per bowlder. Bowlders may be seen occasionally in the river, which have been cut down in this way. There are immense numbers, much the larger part of them on the West Branch, upon which perhaps $20,000 might be expended with advantage to the lumber interest.

In making the examination a continuous mid-channel line of soundings was taken, extending from their confluence at Medway up the East Branch seven miles to Rocky Rips, up the West Branch ten miles to Shad Pond, and on the river fifty-eight and one-half miles to Oldtown. There were taken on the East Branch nine hundred and twenty, on the West Branch five hundred and forty-four, and on the river proper fifty-two hundred and twenty-six soundings, averaging respectively 46, 97, and 60 feet apart. When they were taken the stage of water in the river was somewhat below the average annual lowest stages, and about 4 feet below the annual high-water stage of longest duration. The range on the river between Oldtown and Winn, between lowest and highest water, is stated in Wells's "Water-Power of Maine" to be 11 feet.

The estimates given below, based entirely on a single line of soundings, are rough, and are submitted with a view to giving a sufficiently approximate idea of the labor and expense which the improvement of this river would involve, rather than with the anticipation, in view of the facts above given, that any improvement will be undertaken by the Government.

The estimated quantities of material to be removed are for a channel 75 feet wide and 3 feet deep at the stage of water when the soundings were taken, cut through the obstructions between Oldtown and Winn; and for one 60 feet wide and 2½ feet deep cut through those above Winn, where the river is generally more shallow. Six inches increase in depth, *i. e.*, to 3 feet above Winn, would very much increase the length of excavation.

The obstructions, in the order in which they are met in ascending the river from Oldtown, and the quantity of material to be removed from each, are as follows, viz:

1. A small shoal of gravel about three miles above Oldtown. It is about one hundred yards long, has a minimum depth of water on it in the channel of 2.6 feet, requires a mean increase of depth of two-tenths of a foot, and the removal of about 170 cubic yards of gravel and small bowlders.

2. Several small shoals of gravel about ten miles above Oldtown, and just below Greenbush, in the chute between the left bank and boom and Nebraska Islands. The minimum depth of water on them in the channel is 1.4 feet; the total length of the required excavation about 330 yards; the average depth to cut 6 inches; and the material to be removed, about 1,400 cubic yards of gravel mixed with sand.

3. A small shoal of gravel just above Greenbush, in the short chute between the foot of Sugar Island and the head of Bird Island. The least depth of water in the channel is 2 feet; length of required excavation, about 800 feet; average depth to cut, 6 inches; material to be removed, about 1,100 cubic yards of coarse gravel.

4. Spencer Rips, about thirteen miles above Oldtown. Here bowlders of all sizes up to about 6 feet in diameter are thinly scattered over the river for about one-quarter of a mile, and along about 350 yards of this distance there is a shoal of gravel and small bowlders mixed, over which the water ripples. The least depth of water in the channel is 1 foot; length of required excavation, about 350 yards; average depth to cut, one foot; material to be removed, about 2,900 cubic yards of gravel and small bowlders. The channel between the larger bowlders is sufficiently wide and straight, and none need be removed for steamboats, but about ten of the largest obstruct the running of logs.

5. A shoal of gravel and small bowlders, about midway between Spencer and Ayer's Rips. The least depth of water in the channel is 1.7; length of required excavation, about 375 yards; average depth to cut, seven-tenths of a foot; material to be removed, about 2,200 cubic yards.

6. Ayer's Rips, about fourteen miles above Oldtown, consisting of a shoal of coarse gravel and small bowlders mixed, about 500 yards in length, along about 200 yards of which distance numerous bowlders, varying in size up to about 4 feet in diameter, are scattered about the river. There are also three large bowlders, about 8 feet in diameter, which obstruct the running of logs. Between the larger bowlders the channel for steamboats is sufficiently wide and practicable, although rather tortuous. The minimum depth of water in it is 1.4 feet. The length of the excavation required here is about 530 yards; the average depth to cut, seven-tenths of a foot; and the material to be removed, about 3,100 cubic yards of coarse gravel and small bowlders. The

slope of the river and the current are here somewhat increased, but the latter is not very rapid.

7. A shoal of gravel, sand, and small bowlders, mixed, about one-third of a mile above Ayer's Rips. The least depth of water in the channel is 1.4 feet; length of excavation, about 400 yards; average depth to cut, six-tenths of a foot; material to be removed, about 2,000 cubic yards of gravel, sand, and small bowlders.

8. A small shoal of fine gravel, about 1,200 yards below Passadumkeag Rips. The least depth of water in the channel is 2 feet; length of excavation, about 100 yards; average depth to cut, 6 inches; material to be removed, about 500 cubic yards of fine gravel.

9. A shoal of gravel, immediately below Passadumkeag Rips. The least depth of water in channel is 1 foot; length of excavation, about 430 yards; average depth to cut, 1 foot; material to be removed, about 3,600 cubic yards of gravel.

10. Passadumkeag Rips, about 500 yards below the mouth of the Passadumkeag. These rapids are formed by a slate-ledge, which extends across the river and along it about one-half a mile. Scattered about on the ledge are occasional large bowlders, about fifteen of which are near the channel, from 4 to 11 feet in diameter, and obstruct the running of logs, but are not in the way of steamboats. On either side of the channel, and especially on the left side, jutting out long distances from the bank, are large, jagged masses of ledge, rising 3 or 4 feet above the water. The river is here about 250 yards wide. The channel is about 50 yards from the right bank, about parallel with it, nearly straight, and from 100 to 150 feet wide at its narrowest parts between points of ledge. The least depth of water in the channel is 2½ feet, and is found where it is narrowest. At those points the current is excessively rapid, and the water rough and turbulent. To deepen the water in the channel to 3 feet for a width of 75 feet the length of the excavation required would be about 50 yards; the depth to cut, about 6 inches; and the material to be removed, about 200 cubic yards of solid slate rock.

11. A shoal of gravel and small bowlders, just above Passadumkeag, in the chute between the two Passadumkeag Islands nearest the right bank. The least depth of water in the channel is 1½ feet; the length of the excavation, about 700 yards; average depth to cut, seven-tenths of a foot; material to be removed, about 4,000 cubic yards of gravel and small bowlders.

12. Piscataquis Rips, just above the mouth of the Piscataquis River. These rapids are the worst on the river; they consist of two parts, known as the "upper pitch" and the "lower pitch," between which the river is comparatively unobstructed. The entire length of the rapids from the head of the upper to the foot of the lower pitch is about one and one-half miles. In this distance the river has a great increase of slope, chiefly at the two pitches. The upper pitch is much the worse and the more extensive. It is about one-half a mile long, and consists of a ledge of slate extending along this distance entirely across the river. The planes of stratification of the ledge have a nearly vertical pitch; and it has a very ragged and uneven surface, broken into irregular, sharp, and jagged ridges and isolated points, rising frequently 4 or 5 feet above the water. There are scattered over it numerous bowlders of all sizes up to 5 or 10 feet in diameter. In the channel, which is near the right bank and generally parallel with it, the bed is of solid ledge, occasionally overlaid with bowlders, its slopes steep and irregular; the current extremely rapid, and the least depth of water 1.4 feet. There would be required here, it is roughly estimated, a total length of excavation of about 500 yards, with an average depth to cut of seven-tenths of a foot, and the removal of about 3,000 cubic yards of solid rock. To clear the channel properly for steamboats there should be removed one large bowlder containing about 20 cubic yards, two containing about 5 cubic yards each, and about one hundred of about five tons each. There are also near the channel about fifty rocks which obstruct the running of logs. From the foot of the first pitch to the head of the second the distance is about three-fourths of a mile, along which are scattered a few large bowlders. The channel here is quite tortuous, between shoals of small bowlders; the slope and current much less steep and rapid; and the least depth of water 1.4 feet. The total length of excavation here would be about 800 feet; the average depth to cut, eight-tenths of a foot; and the material to be removed, about 1,600 cubic yards of bowlders, varying in size from about 6 inches to 1 foot or 18 inches in diameter. There are here, also, eight bowlders, containing about 4 cubic yards each, which obstruct steamboat navigation, and four others which obstruct the running of logs.

The second pitch is about one-quarter of a mile long. Here the river again has a greatly-increased slope, and is obstructed by numerous bowlders of all sizes up to about 8 feet in diameter. In the channel, which is the nearer left bank and sufficiently straight, the least depth of water found is 3 feet; the bed is of coarse bowlders, apparently about 2 or 3 feet in diameter; the current very rapid, and the water very rough and turbulent where it dashes down frequent short and steep slopes over the larger bowlders of the bed. To properly clear this channel for steamboats there should be removed six large bowlders, containing about seventeen cubic yards each; twelve of

about six cubic yards each; and twenty containing each about three cubic yards. The one on the lower pitch, about one hundred bowlders, rising from 3 to 7 feet above the water, which obstruct the running of logs.

The owners of the two steamboats which plied on the river between 1850 and 1870 constructed a canal on the left bank, along the bed of a small stream, around these rapids. It is now entirely out of repair, its locks burned and destroyed, and its bed dry.

13. Gordon Rips, about three miles above the mouth of the Piscataquis, and opposite the lower part of Gordon Island, which is separated from the left bank by a small and circuitous chute. These rapids are about a half mile in length, along which distance the river has a considerably increased slope, a rapid current, and contains numerous bowlders of all sizes up to 8 or 10 feet in diameter; a ledge of slate also juts out from Gordon Island. For about two-thirds of the distance from the head of the rapids the channel is parallel with and about sixty yards from the left bank; it then crosses to within about sixty yards of the right bank. The river here is about 250 yards wide, and the channel at its two narrowest parts, between groups of large bowlders, only about 100 feet wide. The bed is of small bowlders, and the least depth of water 2 feet. The length of the excavation would be about 120 yards; the average depth to cut, 6 inches; and the material to be removed, about 500 cubic yards of small bowlders. Twelve bowlders, containing about four cubic yards each, should also be removed.

14. A shoal of gravel about two-thirds of a mile above Gordon Rips. The least depth of water in the channel is 1.7 feet; the total length of excavation, about 350 yards; the average depth to cut, eight-tenths of a foot, and the material to be removed, about 2,300 cubic yards of gravel.

15. A shoal of gravel and ledge immediately below Mohawk Rips. On the shoal the least depth of water in the channel is 1.9 feet; the length of the required excavation, about 300 yards; the average depth to cut, seven-tenths of a foot; and material to be removed, about 1,750 cubic yards of gravel. The ledge is of slate, and is at the lower end of the gravel-shoal. The least depth of water on it in the channel is 1.3 feet. The length of the excavation would be about 100 feet; the average depth to cut, 1 foot; and the material to be removed, about 270 cubic yards of solid slate-rock.

16. Mohawk Rips, about fifteen miles below Winn. Here the river is about 330 yards wide, and is obstructed for about half a mile by a great number of bowlders of all sizes up to 8 or 10 feet in diameter, thickly scattered over it; it has also a considerably-increased slope and a rapid current. The channel is near and nearly parallel with the right bank; is respectively about 60, 75, and 100 feet wide at its three narrowest parts, between groups of large bowlders; has a bowlder bottom, and a minimum depth of 3 feet of water from the head to the lower part of the assemblage of bowlders. From this point downward about 350 yards the channel is shallow, having a least depth of 1.2 feet. The length of the required excavation would be about 350 yards; its average depth, 1 foot; and the material to be removed, about 3,000 cubic yards of small bowlders. To properly clear the channel through these rapids would require the removal of one bowlder containing about 3, one about 5, and two about 7 cubic yards, besides various smaller ones, amounting to about 50 cubic yards. There are also at these rapids about 75 bowlders rising from 3 to 10 feet above the water, which obstruct the running of logs.

17. Mattamiscontis Rips, about fourteen miles below Winn. Here there is a large shoal, about one-fourth of a mile long, of gravel and small bowlders, with numerous larger ones scattered over it, extending from the right bank about two-thirds across the river, which at this place forms a curve, and varies in width from about 200 to about 350 yards. The channel lies around the shoal; is at its narrowest point, between a group of bowlders and the left bank, about 100 feet wide; has a bowlder bottom, and, for a very short distance, a minimum depth of 2 feet. The current is rapid, and the water ripples over the bowlder bottom. There would be required here the removal of about 150 cubic yards of small bowlders.

18. A shoal of gravel and sand opposite the lower end of Mednawcook Island, in the chute next to the right bank. The least depth of water in the channel is 1¼ feet; length of required excavation, about 530 yards; average depth to cut, nine-tenths of a foot; material to be removed, about 4,000 cubic yards of gravel and sand.

19. A shoal of gravel opposite the upper part of Lincoln Islands, in the chute next to the right bank. The least depth of water in the channel is 1 foot; length of required excavation, about 400 yards; average depth to cut, 1 foot; material to be removed, about 3,500 cubic yards of gravel mixed with a small quantity of sand.

20. A shoal of gravel and sand about 400 yards above Lincoln Centre. The least depth of water in the channel is 1.8 feet; length of required excavation, about 500 yards; average depth to cut, 6 inches; material to be removed, about 2,000 cubic yards of gravel and sand.

21. A shoal about three-fourths of a mile below Seabonibus Rips. The least depth of water in the channel is 1.3 feet; length of required excavation, about 450 yards; aver-

age depth, nine-tenths of a foot; material to be removed, about 3,400 cubic yards of small bowlders and gravel.

22. Seabonibus Rips, about five miles below Winn. Here the river is about 150 yards wide, and has along about 200 yards a number of large bowlders scattered over it, between the right bank and the channel, which at its narrowest part, between the bowlders and left bank, is about 50 yards wide. The least depth of water is 2.2 feet; length of the required excavation, about 220 yards; average depth, four-tenths of a foot; material to be removed, about 800 cubic yards of small bowlders.

23. A shoal in the chute between the left bank and Snow Island. The least depth of water in the channel is 1.9 feet; length of the required excavation, about 350 yards; average depth, four-tenths of a foot; material to be removed, about 1,200 cubic yards of fine gravel and sand.

24. A shoal between the head of Swan Island and the foot of Brown's Island. The least depth of water in the channel is 1.6 feet; length of excavation, about 300 yards; average depth, about six-tenths of a foot; material to be removed, about 1,500 cubic yards of fine gravel.

25. Several shoals in chute between the right bank and Brown's Island. The least depth of water in the channel is 1.3 feet; the total length of excavation, about 1,000 yards; average depth, seven-tenths of a foot; material to be removed, about 5,900 cubic yards of gravel.

26. Five Islands Rips. The foot of these rapids is about 300 yards above Winn. They are about 300 yards long, and immediately above them the river is divided into five narrow chutes of five islands. The distance from the head of the islands to the foot of the rapids is about one mile, along which the river-bed is formed in a ledge of slate, which constitutes the obstruction, and which crops out in the river just above the islands, along the banks of the chutes, and in large masses just below the islands, on the left of the channel at the rapids. The width of the river above the islands is about 250 yards, and that of the second chute from the right bank, through which the channel passes, is only 38 yards at its upper and narrowest part. Below this chute the channel over the rapids is near the right bank, and rather crooked, following that bank in a somewhat abrupt turn to the right. The current through the chute is swift, and increases to great rapidity at the rapids, where for about 200 feet the slope is steep and the water rough and turbulent, dashing over the ledge down several short and steep slopes. In the channel, from a point about 300 feet above the islands to the foot of the rapids, the bottom is alternately of ledge and bowlders, which undoubtedly overlie the ledge. The depth of water varies from 1½ to 5 feet. Above the island the minimum depth is 1.9 feet; in the chute it is 1½ feet, and on the rapids 2½ feet. The length of the required excavation (for a channel 2½ feet deep and 60 feet wide) would be about 300 yards; the average depth to cut, six-tenths of a foot; and the material to be removed about 1,200 cubic yards of solid slate rock and bowlders. It is said that in running logs great labor is expended yearly in setting adrift large numbers of logs which gather and lodge in the two left chutes in consequence of their contracting channels and irregular shores. This labor could be saved by the construction of a dam or boom, about 500 feet long, and extending from the left bank of the river obliquely across the heads of these chutes to the left bank of the middle chute.

27. Babcock's Rips, about three-fourths of a mile below Mattawamkeag. Here for about one-quarter of a mile the banks are lined with slate-ledge, and a large number of bowlders of various sizes. Between the latter there is a good channel at least 100 feet wide, having a bottom of coarse bowlders, a strong, smooth current, and a depth varying from 3 to 9 feet, excepting at one point, where it is only 2.1 feet; the material to be removed here is about 100 cubic yards of coarse bowlders from the bed of the channel. There are also eight large bowlders, which obstruct the running of logs.

28. Shoals of gravel between Mattawamkeag and Mattaceunk Rips. Between these two places the distance is about six miles, and the river-bed is a succession of gravel shoals, upon which the least depth of water in the channel is 1 foot; while between them, *i. e.*, between their 2½ feet curve, the average depth is about 3½ feet. The total length of the excavation required here would be about 4,300 yards; the average depth to cut six-tenths of a foot, and the material to be removed about 17,200 cubic yards of gravel, mixed with small bowlders and a trace of sand.

29. Mattaceunk Rips, about seven miles below Medway. These rapids are about one-quarter of a mile long, and consist of a shoal of bowlders, over which are scattered numerous larger bowlders, of all sizes, up to about 10 feet in diameter. The river-bed has a considerably increased slope, and the current is rapid. The channel is tortuous, crossing from the right to the left bank, along which it lies over the steepest and worst part of the rapids. In it the least depth of water is 1 foot, the extreme depth 4, and the average depth 3 feet. The length of the required excavation would be about 60 yards; its average depth seven-tenths of a foot; and the material to be removed about 300 cubic yards of small bowlders. To straighten the channel there should also be removed three bowlders, containing respectively about 16, 12, and 5 cubic yards, and

about thirty containing from one-half to two cubic yards each. There are here also about thirty bowlders which obstruct the running of logs.

30. From Mattaceunk Rips to Salmon-stream Rips, a distance of about two miles. Between these two places the river is much obstructed by shoals of gravel, on which the minimum depth of water in the channel is 1.1 feet, while between their 2½ feet curves the average depth is 3½ feet. The total length of excavation required through these shoals would be about 1,000 yards; the average depth to cut seven-tenths of a foot; and the material to be removed about 4,800 cubic yards of coarse gravel and small bowlders, mixed. The river is about 200 yards wide and the current gentle.

31. Salmon-stream Rips, about four miles below Medway. Here for about one-quarter of a mile the river has a somewhat increased slope, a moderately rapid current, and contains scattered over it numerous bowlders, between which there is a tortuous channel at least 100 feet wide, in which the average depth of water is 4 feet, and the least depth 2½ feet, excepting over two very small groups of bowlders, where it is respectively 1 and 2 feet. The removal of these bowlders from its bed and of several larger ones from its sides to straighten it, might be effected with decided improvement to the channel at an expense, say, of $500.

32. A shoal of gravel about midway between Salmon-stream Rips and Saint Mary Rips. The distance between these two places is about one mile. Between them and this shoal the average depth of water is 4 feet. On the shoal the least depth in the channel is 1.4 feet; the current is swift and the water ripples. The length of the excavation would be about 380 yards; its average depth 6 inches; and the material to be removed, about 1,300 cubic yards of coarse gravel mixed with small bowlders.

33. Saint Mary Rips, about three miles below Medway. Here for about one-quarter of a mile the river has a considerably increased slope, and a bed of bowlders varying from about 6 to about 18 inches in diameter, over which the current is rapid and the water rough. There are also scattered over the river numerous larger bowlders, from 2 to about 5 feet in diameter, which are awash at the low and beneath the surface at the high-water stage. The least depth of water in the channel is 1.4 feet. The length of excavation would be about 170 yards; its average depth seven-tenths of a foot; and the material to be removed about 800 cubic yards of bowlders from the bed of the channel. Just below these rapids the river narrows to about 100 yards wide.

34. A shoal of gravel just below Daisy Rips. The least depth of water in the channel is 1.3 feet; the length of the required excavation about 250 yards; its average depth four-tenths of a foot; and the material to be removed about 700 cubic yards of gravel. The current is rapid.

35. Daisy Rips, about one and one-half miles below Medway. Here, for about 500 feet, the water is shallow and the current rapid over a bed of small bowlders. There are also bowlders 4 or 5 feet in diameter thinly scattered about the river. The least depth of water in the channel is 1 foot. The length of the required excavation about 200 yards; its average depth 1.1 feet; and the material to be removed about 1,500 cubic yards of bowlders.

36. From Daisy Rips to Medway. Between these two places there are three small shoals. The least depth of water on them in the channel is respectively 1.5, 1.9, and 1.5 feet. The total length of excavation through them would be about 270 yards; its average depth seven-tenths of a foot; and the material to be removed about 1,200 cubic yards of gravel mixed with small bowlders.

At Medway, the east and west branches flowing, the former south by east, and the latter in a general southeast direction, unite and form the Penobscot proper. The West Branch is the wider, and discharges the larger volume of water, while the East Branch is the less obstructed.

THE EAST BRANCH.

This stream could be made navigable for boats drawing 2½ feet of water to Rocky Rips, about seven miles above Medway. To that point its average width is about 200 feet.

The obstructions, in the order in which they are met in ascending it, are as follows, viz:

1. From Medway to Ledge Falls, a distance of about two and one-quarter miles. Here there is a succession of gravel shoals. In the channel the average depth of water between them is 3.8 feet. The least depth of water on them in the channel is 1 foot. The total length of the required excavation through them would be (for a channel 2½ feet deep and 60 feet wide) about 1,300 yards; the average depth to cut 1.7 feet; and the material to be removed, about 14,700 cubic yards of gravel. The current is not very rapid, and in many places the water ripples over the gravel.

2. Ledge Falls. Here a ledge of slate extends across the river and forms its bed for a distance of about 700 feet. The strata have a nearly vertical dip and extend, in places, 3 or 4 feet above the water. Over the ledge the river has a greatly increased slope, and an excessively strong and rapid current. At the upper and lower limits of the ledge

the channel between its higher points is, for a few feet, only about 30 feet wide, at which places the water is, respectively, 2.3 and 4 feet deep, runs with extreme rapidity, and is very rough, dashing down slopes having about 1½ and 2½ feet fall in distances of 10 and 30 feet. In the channel the average depth of water on the ledge is 3 feet and the least depth 1½ feet. It is roughly estimated that there would here be required the excavation of about 700 cubic yards of solid slate rock.

3. From Ledge Falls to Rocky Rips, a distance of about four and three-quarter miles. Between these two places there is a succession of gravel shoals. The least depth of water on them in the channel is 1 foot; the total length of the required excavation through them about 1,700 yards; its average depth seven-tenths of a foot; and the material to be removed about 8,000 cubic yards of gravel.

The examination of this branch extended only to Rocky Rips. Above these rapids for fully two miles, embracing them and the "Upper" and "Lower" Grindstone Rips. it is obstructed by large masses of slate-ledge and by immense numbers of bowlders of all sizes up to 15 or 20 feet in diameter; its slope is steep; its current very rapid, and the water in places very shallow.

Above the Upper Grindstone Rips there are, I have been informed, occasional long reaches which are comparatively unobstructed. The entire length of the East Branch is said to be about sixty-three miles. It cannot be made navigable further than to Rocky Rips, at least without enormous expense.

THE WEST BRANCH.

Between Medway and Shad Pond, a distance of about ten miles, this stream is obstructed by the following rapids, viz:

1. Nicaton Rips, just above Medway. Least depth of water in channel, 3 feet; least depth on shoal of bowlders just below. 1 foot.
2. Rocky Beamy Rips, about one and one-half miles above Medway, and one-eighth of a mile long, Least depth of water in channel, 2 feet.
3. Wade Rips. A shoal of bowlders about one-half of a mile long. Least depth of water, for about 200 feet, 1½ feet.
4. Burnt Land Rips, about three miles above Medway and about three-fourths of a mile long. Least depth of water in channel, 2 feet.
5. Rocky Rips, about four miles above Medway and about three-fourths of a mile long; least depth of water in channel, 1 foot.
6. Dolby Rips, about five and one-half miles above Medway, and about three-fourths of a mile long; least depth of water, 2 feet.
7. Ledge Falls, about six and one-half miles above Medway, and about 700 yards long; least depth of water, 1 foot.
8. Jerry Brook Rocks, about seven and one-half miles above Medway, and about one mile long; least depth of water, 2 feet.
9. Pond Falls, about one-quarter of a mile below Shad Pond, and about three-fourths of a mile long; least depth of water, 1 foot.

Shad Pond, through which the West Branch flows, is the upper limit of the examination. It has an area of about three-fourths of a mile square.

All of the above rapids, excepting Nicaton, Wade, and Dolby Rips, are, to use the expression, forests of large bowlders, between which the water flows with a very rapid current, and in a very turbulent manner, over a rough and very steeply sloping bed. At Pond Falls, Jerry Brook Rocks, and Ledge Falls, in addition to the bowlders, there are ledges of slate cropping out in the river. The descent of the bed between Shad Pond and Medway must be great.

The West Branch cannot be made navigable above Medway. It contains an immense number of large bowlders. By blasting off the tops of many of them the running of logs could be much improved.

ESTIMATE OF COST OF IMPROVEMENT.

I.—*Cost of cutting a channel 75 feet wide and 3 feet deep through the obstructions between Oldtown and Winn.*

Order above Oldtown.	Obstructions.	Material. Kind.	No. of cubic yards.	Price per cubic yard.	Amount.
1	A shoal	Gravel and small bowlders	170	$1 00	$170
2	....do	Gravel and sand	1,400	1 00	1,400
3	....do	Coarse gravel	1,100	1 00	1,100
4	Spencer Rips	Gravel and small bowlders	2,900	1 00	2,900
5	A shoal	....do	2,200	1 00	2,200
6	Ayer's Rips	....do	3,100	1 00	3,100
7	A shoal	Gravel, sand, and small bowlders	2,000	1 00	2,000
8	....do	Fine gravel	500	1 00	500
9	....do	Gravel	3,600	1 00	3,600
10	Passadumkeag Rips	Slate rock	200	15 00	3,000
11	A shoal	Gravel and small bowlders	4,000	1 00	4,000
12	Piscataquis Rips	Slate rock	3,000	15 00	45,000
		Small bowlders	1,600	3 00	4,800
		Large bowlders	546	3 00	1,638
13	Gordon Rips	Small bowlders	500	3 00	1,500
		Large bowlders	48	3 00	144
14	A shoal	Gravel	2,300	1 00	2,300
15	....do	....do	1,750	1 00	1,750
	A slate ledge	Slate rock	270	15 00	4,050
16	Mohawk Rips	Small bowlders	3,000	3 00	9,000
		Large bowlders	72	3 00	216
17	Mattamiscontis Rips	Small bowlders	150	3 00	450
18	A shoal	Gravel and sand	4,000	1 00	4,000
19	....do	....do	3,500	1 00	3,500
20	....do	....do	2,000	1 00	2,000
21	....do	Small bowlders and gravel	3,400	2 00	6,800
22	Seabonibus Rips	Small bowlders	800	3 00	2,400
23	A shoal	Gravel and sand	1,200	1 00	1,200
24	....do	Fine sand	1,500	1 00	1,500
25	Several shoals	Gravel	5,800	1 00	5,800
	Total				122,018

II.—*Cost of cutting a channel 60 feet wide and 2½ feet deep through the obstructions between Winn and Medway.*

Order above Oldtown.	Obstructions.	Material. Kind.	No. of cubic yards.	Price per cubic yard.	Amount.
26	Five-Island Rips	Slate rock and bowlders	1,200	$10 00	$12,000
27	Babcock's Rips	Coarse bowlders	100	3 00	300
28	Several shoals	Gravel and small bowlders	17,200	1 00	17,200
29	Mattaceunk Rips	Large and small bowlders	370	3 00	1,110
30	Several shoals	Coarse gravel and small bowlders	4,800	2 00	9,600
31	Salmon-stream Rips	Large and small bowlders			500
32	A shoal	Coarse gravel and small bowlders	1,300	2 00	2,600
33	Saint Mary Rips	Small bowlders	800	3 00	2,400
34	A shoal	Gravel	700	1 00	700
35	Daisy Rips	Small bowlders	1,500	3 00	4,500
36	Several shoals	Gravel and small bowlders	1,200	2 00	2,400
	Total				53,310

III.—*Cost of cutting a channel 60 feet wide and 2½ feet deep through the obstructions between Medway and Rocky Rips, on the East Branch.*

Order above Medway.	Obstructions.	Material. Kind.	No. of cubic yards.	Price per cubic yard.	Amount.
1	Several shoals	Gravel	14,700	$1 00	$14,700
2	Ledge Falls	Slate rock	700	15 00	10,500
3	Several shoals	Gravel	8,000	1 00	8,000
	Total				33,200

SUMMARY.

Cost of improvement between Oldtown and Winn	$122,018
Cost of improvement between Winn and Medway	53,310
Cost of improvement between Medway and Rocky Rips	33,200
Total	208,528
Add for contingencies and engineering expenses, (say 15 per cent.)	31,279
Aggregate	239,807

I cannot discover a necessity for the removal of these obstructions by the Government, nor the expediency of the expenditure by it of any such sum of money upon this part of this river for the purpose of improving it for steamboat navigation, cut off, as it is, from tide-water navigation. There are a great number of streams, more or less remote tributaries to the great rivers in the country, for the improvement of which large appropriations could, with as good reason, be expected.

In regard to the expenditure of from $20,000 to $50,000 upon bowlders, chiefly in the West Branch, to improve the running of logs, it is a question whether, with justice, such an expenditure should not be made rather by the lumber interest than by the Government. It would result, probably, in benefit chiefly to a comparatively very small number of persons extensively interested in lumber and owners of large tracts of land in the lumber region.

The actual descent of the river between different places herein given is taken from a work on the "Water-Power of Maine," by the superintendent of the hydrographic survey of that State.

Respectfully submitted.

W. S. STANTON,
Captain of Engineers, U. S. A.

Lieut. Col. GEO. THOM,
Corps of Engineers, U. S. A.

Y 23.

SURVEY OF PORTSMOUTH HARBOR, NEW HAMPSHIRE.

UNITED STATES ENGINEER OFFICE,
Portland, Me, December 13, 1873.

GENERAL: I have the honor to submit the following report on the survey of Portsmouth Harbor, New Hampshire:

This survey was called for by act of Congress approved March 3, 1873, "making appropriations for the repair, preservation, and completion of certain public works on rivers and harbors, and for other purposes," and was made under my instructions, in June and July last, by my assistant engineer, Mr. Sophus Haagensen. His report and map of the same, also prepared under my direction, are herewith submitted.

The object of this survey was the building of a breakwater between

Gerrish's Island and Wood Island, at the outer entrance of the harbor. The site of the proposed breakwater is a ridge or bar connecting these two islands, the shortest distance between them being 1,330 feet at high water and 872 feet at mean low water, while at extreme low water this ridge or bar is uncovered nearly its whole length. This bar consists of coarse shingle, intermixed with large bowlders, covering a ledge which crops out at several places above the 18-foot curve, forming Wood Island, Whale's Back, White Island, Horn Island, and a number of rocky points, dry at half tide, scattered between the high and low water line of Gerrish's Island. The solid and unchanging character of this bar affords a very favorable foundation for the breakwater proposed.

The estimated cost of this work, built of rubble-stone as shown on the drawing, and for a length of 1,376 feet, is $150,000.

The extent to which the commerce of this country would be promoted by the proposed work, as plainly seen on referring to the accompanying sketch of this harbor, would be very great, in the large increase of safe anchorage-ground that would thereby be afforded to the vessels of war connected with the navy-yard at this place, as well as to the numerous vessels engaged in the coasting and foreign trade, and in affording a good harbor of refuge, during southeast gales, to fishing and coasting vessels on reaching the outer harbor.

This work would derive increased importance from the fact that this harbor, thus enlarged and improved, would be well protected, and commanded by Fort Constitution and Fort McClary and the new batteries now in process of construction on Gerrish's Island and Jerry's Point.

Respectfully submitted.

GEO. THOM,
Lieut. Col. of Engineers, Brt. Brig. Gen. U. S. A.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

Report of Mr. Sophus Haagensen, Assistant Engineer.

UNITED STATES ENGINEER OFFICE,
Portland, Me., November 29, 1873.

GENERAL: In obedience to your instructions of June 25, I proceeded to Fort Constitution, Portsmouth Harbor, New Hampshire, to make a survey such as might be necessary for locating a breakwater between Gerrish's Island and Wood Island, and making an estimate of the cost thereof.

The field-work was commenced June 28, and finished July 10, 1873.

I have the honor to submit the following report upon this survey, as well as a drawing, comprising a map of the survey, drawn to a scale of 200 feet = 1 inch, or 1 : 2400, showing the location of the proposed breakwater, a map of Portsmouth Harbor, from Whale's Back light to the Narrows, in a scale of 1 : 20,000, from United States Coast Survey maps, a cross-section of the proposed breakwater, and a length profile through the axis of the same.

The survey was commenced by measuring a base-line on Gerrish's Island, A-B, (794.58 feet long, horizontal distance,) and from this base-line triangulation was extended to various fixed points on Gerrish's and Wood Islands; the location of Whale's Back light (old and new position) and Portsmouth light was also determined, in order to use those two points, viz, old position of Whale's Back light and Portsmouth light, as a base for comparison between the present survey and that of Capt. Howard Stansbury, United States Topographical Engineers, map of Portsmouth Harbor, New Hampshire, 1842-'43-'44. Details were drawn on the plane-table, and twelve lines of soundings run over the bar between Wood and Gerrish's Islands, the proposed site of the breakwater. Each sounding was located on a certain range by intersecting sights from a plane-table stationed ashore. The soundings were either taken with a 16-foot pole, or with a lead attached to a galvanized-iron chain; no lead-line was used. Nu-

merous borings were made in order to ascertain the character and stability of the foundation of the proposed breakwater.

The soundings are all referred to the plane of mean low-water, which is 16 feet below the casemate of Fort Constitution; the tide-staff was placed on the wharf at Fort Constitution; the mean rise and fall of tide here is 8.6 feet.

The site of the proposed breakwater is a high ridge or bar connecting Gerrish's Island and Wood Island. The shortest distance between these two islands is, at high-water, 1,330 feet; at mean low-water, 872 feet; at extreme low-water this bar is uncovered almost its whole length, leaving only a short run close to Wood Island, with not exceeding 2½ feet of water in it for a distance of only 200 feet.

This bar consists of coarse shingle, intermixed with heavy bowlders, covering the ledge which is cropping out at numerous places above the 18-foot curve forming Wood Island, Whale's Back, White Island, Horn Island, and a number of rocky points dry at half-tide, scattered between the high and low water lines of Gerrish's Island.

A careful comparison of the present survey with that of Captain Howard Stansbury, United States Topographical Engineers, made thirty years ago, shows no change in the contour-lines, thus indicating that this bar has not been subjected to changes during this period. The coarse material of which it is composed, and the easy slopes, (line of greatest depression has an outward slope of 1:125, an inward of 1:37,) promise a solid foundation and stability to the breakwater which may be built on the bar connecting Wood Island with Gerrish's Island.

The breakwater is proposed to be built of heavy rubble-stone work (riprap) throughout; the top to be 12 feet wide in Ref., 16 feet above mean low-water, or 7.4 feet above mean high-water, which is very nearly the height of the adjoining shores of Gerrish's and Wood Islands, viz: 18.20 feet and 15.05 feet. The outward slope to be 1:2, the inner slope 1:1. (See Figs. 1 and 2.)

The axis or midline of the top will be a straight line conforming as near as practicable to the line of highest elevation of the bar. Two holes drilled in the solid ledge, one on Gerrish's Island, and one on Wood Island, mark this line, the direction of which is N. 39° 6′ E., or N. E. ¼ N., true bearing. The distance between these points is 1,392 feet. The rock round the hole on Gerrish's Island is in ref. 18.20 feet above mean low-water; on Wood Island, 15.05.

The length of the breakwater on top will be 1,376 feet; for a distance of 556 feet the breakwater will rest on solid ledge; for a distance of 820 feet the foundation will be heavy bowlders and coarse shingle.

The estimate cost of the proposed breakwater is as follows:

23,000 cubic yards of riprap work, at $6 per cubic yard	$138,000
Contingencies, say	12,000
Total cost of breakwater	150,000

The advantages to Portsmouth Harbor derived from this breakwater will be evident from the accompanying map of the harbor, in a scale of 1:20,000.

A red dotted line is drawn from Wood Island through the northeast extremity of Great Island, (Fort Constitution.) The part of the harbor on the northeast side of this line is at present very much exposed during southeasterly blows, especially at high tide, where a direct wave 1,300 feet in width enters the harbor between Wood and Gerrish's Islands, and renders this part of the harbor unsafe as an anchorage-ground. To be safe in a southeast gale, vessels must pass Fort Constitution, and anchor up close to the north shore of Great Island, or close to the east shore of Clark's Island. By closing up the gap between Wood and Gerrish's Islands with a breakwater, as now proposed, the above-mentioned area between Wood Island, Fishing Island, and Kittery Point will be perfectly free from undertow, or an addition made to the valuable anchorage-ground of an area covering 612 acres at high-water; the part of this area with more than 18 feet of water at mean low-water (27 feet at high-water) measures 270 acres.

Not only will this large part of the harbor be improved by the proposed breakwater, but the harbor between Fort Constitution and Clark's Island will, during southeast gales, be free from the swell which is at present produced by the spreading of the wave entering the harbor between Gerrish's and Wood Islands.

The building of the proposed breakwater will thus afford efficient protection to the numerous fishing-vessels and coasters using the outer part of Portsmouth Harbor as a harbor of refuge during southeast gales, and increased anchorage-ground will be obtained at a comparatively small expense.

Very respectfully, your obedient servant,

SOPHUS HAAGENSEN,
Assistant Engineer

Bvt. Brig. Gen. GEO. THOM,
Lieut. Col. Corps of Engineers.

Y 24.

SURVEY IN IPSWICH BAY, MASSACHUSETTS, AT HODGKINS COVE.

UNITED STATES ENGINEER OFFICE,
Portland, Me., December 13, 1873.

GENERAL: I have the honor to submit the following report on the survey "in Ipswich Bay, Massachusetts, at Hodgkins Cove."

This survey, called for by act of Congress approved March 3, 1873, "making appropriations for the repair, preservation, and completion of certain public works on rivers and harbors, and for other purposes," was made under my instructions in June last, by Mr. Sophus Haagensen, assistant engineer, and his report thereon, dated November 14, 1873, with the accompanying map, also made under my instructions and in consultation with me, are herewith submitted with my approval.

The object of this survey was "to ascertain the practicability of a harbor of refuge by building a breakwater there," and on referring to the accompanying report and map it will be seen that there would not be any engineering difficulties attending the building of such a work; and that the only suitable locations for it would be either upon the Lower or the Upper Plum Cove Rocks. If located upon the Lower Plum Cove Rocks it would afford about 23 acres of good anchorage-ground for a depth of 18 feet, and 32 acres for a depth of 12 feet, at mean low-water, and 40 acres for the smaller class of vessels that would resort to this harbor; the cost of the work being estimated at $640,000.

But if located on the Upper Plum Cove Rocks, while it would thereby inclose a much larger space, it would afford only about 30 acres of additional anchorage-ground, with the serious objection that would ensue from having the anchorage endangered by inclosing the Lower Plum Cove Rocks. The estimated cost of a work at this place (viz, Upper Plum Cove Rocks) is $1,130,000.

The advantages of location offered by the Lower Plum Cove Rocks over the Upper consist, therefore, in its less cost, and in affording a more secure anchorage, as well as in the partial protection that would be afforded to a breakwater at that place by the Upper Plum Cove Rocks in their receiving the first shock of the northeasterly gales.

The extent to which the commerce of the country would be promoted by such a work is clearly seen on examining the accompanying sketch of this part of the coast, bearing in mind that the most dangerous winds that occur here are the northeast gales, and that when fishing, coasting, and other vessels are now caught in those gales in Ipswich Bay, they have to run either for Portsmouth or Gloucester Harbors, their sailing distance apart being thirty-seven miles, or else have to make for Newburyport, Ipswich, Essex, or Annis Squam Harbors, which, owing to the bars at their entrance, are dangerous to enter, except in moderate weather and in favorable stages of the tide. This breakwater would afford a much-needed shelter for the numerous vessels that are always found in this bay, for the want of which a large number of vessels are lost from year to year.

For a more definite understanding of the location and plan of the work proposed, reference is asked to the accompanying report and drawing.

Respectfully submitted.

GEO. THOM,
Lieut. Col. of Engineers, Bvt. Brig. Gen., U. S. A.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

Report of Mr. Sophus Haagensen, Assistant Engineer.

UNITED STATES ENGINEER OFFICE,
Portland, Me., November 14, 1873.

GENERAL: In obedience to your instructions of May 28, the survey of Hodgkins Cove, Ipswich Bay, Massachusetts, with a view to ascertain the practicability of a harbor of refuge by building a breakwater there, was commenced June 6, 1873, and field-work completed June 24.

I have the honor to submit the following report upon this survey, as well as a drawing, comprising a map of the survey, drawn to a scale of 200 feet = 1 inch, or 1 : 2400, showing location of the proposed breakwater; a map of the coast from Gloucester Harbor, Massachusetts, to Portsmouth Harbor, New Hampshire, (from United States Coast Survey maps,) in a scale of 1 : 200,000; a length profile through axis of the proposed breakwater, and a cross-section of the breakwater, showing details of construction.

The survey was commenced by measuring a base-line, A, B, C, from which various fixed points were determined by triangulation. From the triangulation-points the shore topography was drawn on the plane-table, and ranges for sounding laid out.

All the soundings were taken on ranges, and the location of each one determined by sights from the plane-table stationed ashore. The soundings were either made with a 16-foot pole or with a lead attached to a galvanized-iron chain; no lead-line was used.

The plane of reference, to which the soundings are reduced, is the mean low-water as determined by sixteen consecutive low-waters observed on a tide-staff placed on Cape Ann Granite Company's wharf. This plane is 11.53 feet below the bench made at this place, the top of an iron bolt set in the coping of the stone pier. The mean rise and fall of tide is 9.0 feet.

Hodgkins Cove is a part of Ipswich Bay, situated on the northwest side of Cape Ann, distant one mile to the northeast from Annis Squam light. A rocky promontory, Davis Neck, projects at this point in a northwesterly direction from the shore, and between the northeasterly side of this and the high rocky shores of Cape Ann the bottom of the ocean slopes gradually up from a depth of 34 feet at low water, forming a natural anchorage-ground, sheltered for west, south, and southeast winds, but without any protection against north, northeast and east winds. The bottom affords good holding-ground for vessels, being composed of blue clay, covered with a thin layer of fine white and speckled sand.

The most dangerous winds on this part of the coast are northeasterly gales. Coasters and fishing-vessels caught in a northeast gale in Ipswich Bay will now have to make either Portsmouth Harbor, or round Cape Ann for Gloucester Harbor. The sailing-distance between these two harbors is thirty-seven miles. All the harbors on Ipswich Bay, Newburyport, Ipswich, Essex, and Annis Squam Harbors are "barred" harbors, dangerous to enter except in fair weather and during the last part of the flood-tide, when there is sufficient depth of water over the bars to allow vessels of deep draught to pass over them.

A glance at the map of the coast between Portsmouth and Gloucester Harbors will at once show the importance of having a harbor of refuge at this part of the coast, and the advantageous location of Hodgkins Cove for such a harbor. Situated as it is, on the south side of Ipswich Bay, vessels in any part of the bay, or coasters in any place between the north point of Cape Ann and Portsmouth Harbor, (a distance of twenty-six miles,) would have a fair wind and a short sailing-distance, seeking this place as a harbor of refuge for a northeast or east wind. The largest class of vessels would be able to enter the proposed harbor at all stages of the tide, there being 34 feet of water at low-tide in the entrance (see map of survey) between Davis Neck and the end of the proposed breakwater.

Four miles to the north of Hodgkins Cove is a fishing-bank, where numerous fishing-vessels are always found. A large number of these are lost every year in their attempts to make Ipswich or Annis Squam Harbors during a northeast blow. A harbor at Hodgkins Cove would greatly benefit the fishery in Ipswich Bay.

The needed protection against northerly and easterly winds, which would make Hodgkins Cove a safe harbor of refuge for all classes of vessels, would be obtained by building a breakwater from the shore in a westerly direction, curving towards Davis Neck, and leaving an entrance which is 800 feet wide in the high-water line, and 450 feet clear opening in a depth of 18 feet below mean low-water. This width would be ample to enable vessels to sail in with head wind (east) and at the same time not so large that the harbor basin would be affected by the swell in the entrance.

The end of the breakwater is carried out so far from the shore as to be directly north of the extremity of Davis Nick, thus excluding all northerly and easterly undertow from the harbor, (the entrance faces westward,) but no undertow is created by the wind blowing from this direction; there is only three miles open water, and shoal water at that, between the entrance and the opposite shore.

The following figures will give an idea about the size of the proposed harbor inside the entrance-line drawn from the outer end of the breakwater to point east on Davis Nick:

Area in the high-water line	63 acres.
Area in the low-water line	48 acres.
Area in the 6-foot curve	39 acres.
Area in the 12-foot curve	32 acres.
Area in the 18-foot curve	23 acres.

Thirty-two acres of the proposed harbor would thus have from 12–33 feet of water at mean low-water, or from 21–42 feet at high-water. It is estimated that about one hundred coasting and fishing vessels could anchor up in the harbor without danger of fouling.

The details of the construction of the breakwater are illustrated on the map by Figs. 1 and 2, representing respectively a cross-section through the breakwater at the greatest water depth, and a length profile through the axis of the breakwater.

The main body of the breakwater is proposed to be built of riprap work up to ref. 10, or 1 foot above mean high-water, having a width at the top of 22 feet, an inner slope of 1:1, and an outer slope of 1:2. On top of the riprap work a stone wall 10 feet high carries the top of the breakwater up to ref. 20, or 11 feet above mean high-water. This stone wall is to be built of dimension-stone, laid in three courses of headers and stretchers, with a concrete backing and a course of heavy coping-stone 12 feet wide.

The location of the axis of the breakwater, or the middle of the coping, might be described as follows: starting from the shore in a direction W. 26° 20′ N. (true bearing) with a straight line through the iron bolt K, on Lower Plum Cove Rocks, for a distance of 879 feet; thence tangent to this an arc of a circle with radius 1,000 feet for a distance of 725 feet, subtending an angle of 41° 31′; thence tangent to this arc in a straight line running in a direction W. 15° 11′ S., for a distance of 220 feet. This point would be the center of an octagonal stone pier 34 feet in diameter, to serve as a foundation for a light-house.

The total length of the breakwater on top would thus be 1,841 feet; the total length on the bottom measured to the foot of the slope 1,918 feet. For 640 feet of this distance the breakwater would rest on solid ledge, and for 1,278 feet on solid clay bottom.

The estimated cost of this breakwater would be as follows:

1. Riprap work, 140,340 cubic yards, at $3	$421,020
2. Dimension-stone work, 5,550 cubic yards, at $20	111,000
3. Concrete, 5,081 cubic yards, at $10	50,810
	582,830
Contingencies, say	57,170
Total cost of breakwater over Lower Plum Cove Rocks	640,000

The greatest facilities for building a breakwater of the above description at the least cost exist here; the whole shore being solid granite ledge, a quarry can be opened anywhere in the immediate vicinity of the breakwater; stone of any desired dimensions quarried and carried on a railway-track to the end of the breakwater in process of construction.

An estimate has also been made for the construction of a breakwater starting at a point 1,580 feet farther to the north of the above-described, running over the Upper Plum Cove Rocks, curving toward Davis Neck, and terminating in the same point as the first-described.

The entrance would in this latter case be the same as in the first, but the inclosed area would be considerably enlarged, viz:

Area in the high-water level would contain	125 acres.
Area in the low-water level would contain	104 acres.
Area in the 6-foot curve would contain	90 acres.
Area in the 12-foot curve would contain	76 acres.
Area in the 18-foot curve would contain	61 acres.

It must be remarked that in this case the Lower Plum Cove Rocks would be a danger in the harbor, and that the additional valuable anchorage-ground would only be 31 acres, thus hardly doubling the capacity of the first-described harbor, *i. e.*, with a breakwater located over Lower Plum Cove Rocks.

The cost of this larger breakwater, having the same cross-section as above described but a length on top of 3,070 feet, and a length on the bottom of 3,147 feet would be:

1. Riprap work, 254,031 cubic yards, at $3	$762,093
2. Dimension-stone work, 9,268 cubic yards, at $20	185,360
3. Concrete, 8,197 cubic yards, at $10	81,970
	1,029,423
Contingencies, say	100,577
Total cost of a breakwater over Upper Plum Cove Rocks	1,130,000

It is a question whether the advantages to be gained by building the breakwater over Upper Plum Cove Rocks, namely, an increase of the capacity of the inclosed harbor, would warrant the increased cost of half a million dollars. The strongest argument in favor of the first project, (viz, a breakwater over the Lower Plum Cove Rocks,) is the fact that in this case the Upper Plum Cove Rocks would naturally be an auxiliary breakwater, taking the first shock of the heavy northeast rollers, whereas a breakwater over the Upper Plum Cove Rocks would have to stand the direct blow of the heavy northeast seas.

Very respectfully, your obedient servant,

SOPHUS HAAGENSEN,
Assistant Engineer.

Bvt. Brig. Gen. GEO. THOM,
Lieut. Col. of Engineers.

Y 25.

SURVEY OF PLYMOUTH HARBOR, MASSACHUSETTS.

UNITED STATES ENGINEER OFFICE,
Portland, Maine, February 14, 1874.

GENERAL: I have the honor to submit herewith a report and map on the survey of Plymouth Harbor, Massachusetts, made under my instructions by Mr. Sophus Haagensen, assistant engineer, as directed by Department letter of December 12, 1873, in compliance with a resolution of the House of Representatives, dated December 10, 1873, by which the Secretary of War was requested to cause an examination or survey to be made of that harbor, "with a view to dredging and improving the same, so as to afford greater protection and facilities to commerce," and "to report upon the feasibility of making such improvement, and the probable cost thereof."

The improvement of this harbor has hitherto consisted in the protection and preservation, by means of bulkheads and jetties and otherwise, of Long Beach, which alone forms the harbor, as shown on the accompanying drawing. For this work small appropriations have been made by Congress, from year to year, with most successful results; for the continuance of which an appropriation of $5,000 has been asked for the fiscal year ending June 30, 1875.

To improve the harbor itself by dredging, as now proposed, would require the extension of the present main channel from a point one mile above "The Beacon," where it deflects abruptly to the westward, up to the outer end of Long Wharf, so as to have a depth of not less than six feet at mean low-water, or 16 feet at mean high-water.

To make this portion of the harbor practicable for "beating up" with sailing-vessels would require a width of not less than 500 feet, which would necessitate the excavation of about 80,000 cubic yards of hard sand on the "Middle Ground" and "Splitting-Knife" Bars, which obconstruct the present channel, and about 320,000 cubic yards of mud and clay between the "Middle Ground" and "Long Wharf," at a probable cost of not less than $176,000, and with a likelihood that the improvement would be but temporary, as the same causes which have already

produced the existing shoals would, it is more than probable, reproduce them.

Should it be decided to improve this harbor by dredging, it is recommended that it should be applied to the opening of a channel 100 feet in width and 6 feet in depth at mean low-water, from the end of Long Wharf outward in continuation of the present main channel, above the "Middle Ground," as shown on the accompanying drawing. A channel of this width would enable vessels to be towed up to the vicinity of the wharves of the town, and would probably be kept open by the scour of the ebb-tide deflected into it from "Town Brook."

The probable cost of this channel is as follows, viz:

64,000 cubic yards of dredging, at 40 cents per cubic yard	$25,600
Adding for contingencies, say	2,400
Total	28,000

Further details and information in regard to this harbor, as obtained by survey, will be found in the accompanying map and report.

The extent to which the commerce of the country would be promoted by the improvement of this harbor, as above projected, is stated in the accompanying communication of the collector of customs of the port of Plymouth.

Respectfully submitted.

GEO. THOM,
Lieut. Col. of Engineers, Bvt. Brig. Gen., U. S. A.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

Report of Mr. Sophus Haagensen, Assistant Engineer.

UNITED STATES ENGINEER OFFICE,
Portland, Me., February 14, 1874.

GENERAL: In pursuance of your instructions of January 10, I proceeded to Plymouth, Mass., on January 12, and made an examination of the harbor, with a view to improving the same by dredging. I have the honor to submit the following report upon this examination, as well as a drawing of the harbor on a scale of 1:10,000:

The part of the harbor embracing the main channel, and the approaches to the wharves in the town of Plymouth, was surveyed, and the characteristic soundings platted on the accompanying map. The northern part of Plymouth Beach is taken from the survey made in 1872, in connection with the improvement of Plymouth Beach; the rest of the map is taken from United States Coast-Survey charts of 1854 to 1857.

The plane of reference, to which the soundings are reduced, is the mean low-water, as determined from previous surveys, the bench-mark of which is a spike in a wharf-pile at the end of Long Wharf. Said spike is in ref. 7.56 above mean low-water. Levelings were made from this to the floor of the monument over Plymouth Rock, (sill between columns,) which is a permanent bench in ref. 17.24 feet above the plane of reference. The mean rise and fall of tide is 10.1 feet.

Vessels entering Plymouth Harbor from the "main ship-channel," and the "Cow Yard," have a continuous 12-foot channel at low-water, of a width not less than 150 feet to within a distance of half a mile from the wharves in Plymouth. It runs close to the low-water line of Plymouth Beach to a point a mile distant from Plymouth Beacon, where it turns and runs for half a mile in a direction perpendicular to the beach; thence it runs parallel to the wharves in the town, distant about half a mile from the same. Between the channel and the wharves are flats more or less dry at low-water.

Of the numerous drains or gullies in these flats, the "Town Brook" is the most important, making from one to two feet depression in the flats in front of the wharves in Plymouth.

The depth along the mid-line of the channel varies greatly. For the first half mile from the "Cow Yard" it does not average more than 16 feet at low-water. Here are the so-called "tussocks"--small hills or bunches of sand scattered over the bottom.

The shoalest sounding found in them was 9½ feet at mean low-water. As soon as the point of Plymouth Beach is passed the channel, sheltered by the bold shore of the beach, deepens, so that a continuous 18-foot channel, (in places as deep as 29 feet,) at mean low-water, can be followed as far as to the "Middle Ground." This shoal divides the main channel in two narrower channels. The northernmost of these is the best, being at least 150 feet wide between the 12-foot curves, and having from 15 to 31 feet soundings along its mid-line. The channel south of the "Middle Ground" has only half the width of the former, and has 6 feet less water in it.

The width of the "main channel" at low-water is not large enough for a beating-channel, and no reasonable amount of dredging would make it a beating-channel at low-tide.

To improve the channel, so that vessels drawing 16 feet could beat up its whole length at high-water, would require the removal of two shoals, viz, "Splitting Knife" and "Middle Ground," to a depth 6 feet below mean low-water. Both these shoals are banks formed of hard white sand, and the above-named improvement would require at least 80,000 cubic yards of dredging, at a cost of not less than $40,000. To make this work of any value to navigation would, moreover, necessitate the continuation of a channel of the same width (500 feet between the 6-foot curves) through the flats, up to the town wharves, a work which would require the additional removal of 320,000 cubic yards of mud and clay. It is not probable that such a channel would be permanent. The shoals would very likely form again, especially the "Middle Ground," of which the greatest part would be left undisturbed below the 6-foot plane, and there would not be sufficient scouring-power to keep an artificial channel of 500 feet width through the flats open. A good beating-channel from the "Cow Yard" to the wharves in Plymouth would thus involve an expense of not less than $176,000, without any likelihood of permanency; whereas a good towing-channel could be made for vessels of the same class at a comparatively small expense, and with greater promise of permanency.

To obtain a good towing-channel for vessels drawing 16 feet from the "Cow Yard" up to the wharves in Plymouth, no improvement is needed in the natural channel up to within 2,400 feet of the wharves; from here a channel would have to be excavated through the flats to a depth of 6 feet below mean low-water—that is, 16.1 feet below mean high-water. This channel would connect the depression in front of the town wharves with the natural channel, and it is through that the scour of the "Town Brook" would be sufficient to keep a channel of 100 feet width open.

Borings were made along the line of this proposed channel, showing that the material to be excavated is soft clay. Below the 6-foot plane the bottom is harder and gravelly.

The amount of material to be excavated to obtain a channel through the flats of a width of 100 feet, and a depth of 6 feet at mean low-water, (16.1 feet at mean high-water,) is estimated at 50,700 cubic yards *in situ*, or with an increase of 25 per cent. by loosening, at 64,000 cubic yards measured in the scows. The cost of removal and dumping the same (the nearest dumping-place is the "Cow Yard," two miles from the place of dredging) is estimated at 40 cents per cubic yard, as measured in the scows.

64,000 cubic yards of excavation, at 40 cents	$25,600
Contingencies, say	2,400
Cost of improvement	28,000

Very respectfully, your obedient servant,

SOPHUS HAAGENSEN,
Assistant Engineer.

Bvt. Brig. Gen. GEO. THOM,
Lieut. Col. of Engineers.

Commercial statistics.

CUSTOM-HOUSE, PLYMOUTH, MASS.,
Collector's Office, February 12, 1874.

SIR: Your letter of January 30 is received, and in answer I beg leave to say that during the last year the amount of duties paid in Plymouth was $27,571. The number of vessels belonging to the port, and documented here, is 58, amounting to 3,154 $\frac{18}{100}$ tons. A large proportion of these vessels are engaged in the fisheries, the product of which in 1873 was about $180,000. A few are engaged in the coasting-trade, carrying coal, iron, and assorted cargoes of furniture, hollow ware, plaster, sugar, molasses, and fish, to and from Plymouth. The total coasting-trade of the port during last year comprised 59 cargoes of coal, amounting to 12,000 tons; 18 cargoes of iron, amounting to 2,321 tons; 31 cargoes of lumber, amounting to 3,100,000 feet; 3 cargoes of gypsum,

molding-sand, and stone; two cargoes of corn, amounting to 8,000 bushels; 18 cargoes of salt, amounting to 23,000 bushels.

Besides these there are sundry cargoes of wood, ashes, and other articles difficult to enumerate.

The great difficulty of entering the harbor and reaching the wharves necessitates the more expensive importation of lumber, iron, and corn by rail, the amount of the latter article reaching about 60,000 bushels the past year. It is difficult to estimate the advantage which would be derived from a channel 6 feet deep to the wharves at low-tide, but it is clear to all persons of any experience in navigation here that many obstacles would thus be removed which cause delay and expense in receiving and discharging cargoes, and that new inducements would exist for a large increase of our commerce. Plymouth is already a place of considerable importance as a manufacturing town, its products reaching the sum of $3,000,000 per annum; its water-power and general facilities for a large increase of business promise the best results from the improvement of the harbor which is now contemplated.

I trust, sir, that the enterprise will not end with a mere survey, but that it may be carried on to a successful and speedy completion.

I am, with respect, your obedient servant,

THOMAS LORING,
Collector.

GEORGE THOM,
Lieut. Col. of Engineers, Bvt. Brig. Gen., U. S. A.

APPENDIX Z.

ANNUAL REPORT OF MAJOR N. MICHLER, CORPS OF ENGINEERS, FOR THE FISCAL YEAR ENDING JUNE 30, 1874.

UNITED STATES ENGINEER OFFICE.
Portland, Oregon, July 24, 1874.

SIR: I have the honor to submit herewith my annual reports upon works of river and harbor improvements, and of surveys and examinations under my charge, for the fiscal year ending June 30, 1874.

In obedience to Special Orders, No. 179, War Department, Adjutant-General's Office, Washington, September 8, 1873, I relieved Major H. M. Robert, October 22, 1873, of all his duties, including that of Light-House Engineer of the Thirteenth Light-House District.

Very respectfully, your obedient servant,

N. MICHLER,
Major of Engineers, U. S. A.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

Z 1.

IMPROVEMENT OF THE LOWER WILLAMETTE AND COLUMBIA RIVERS FROM PORTLAND, OREGON, TO THE SEA.

LOWER WILLAMETTE RIVER, OREGON.

The following improvements were projected and executed during the fiscal year.

Mouth of Willamette Bar.

The building of the United States dredger was not completed and in readiness for action until the end of August, 1873. The delay was

caused by the great conflagration in Portland during that month. On the 1st of September the dredger, dump-scows, and wood-scow were towed to the mouth of the river by the steam-tug Ben Holliday, and the operation of dredging the bar commenced. Four cuts, each 30 feet in width, were made to the depth of 17 feet, opening a channel-way of 1,800 feet in length by 120 feet in width. The quantity of sand and mud removed amounted to 8,550 cubic yards. The work at this point was completed by the 19th of November.

Post-Office Bar.

The dredger was moved up to this locality from the mouth of the river, a distance of four miles, and soon after began to operate. The latter work was suspended December 11, in consequence of the great inclemency of the weather, ice forming to such an extent as to make it necessary. It was resumed in the following season on the 11th of March, and the cut was finished by the 31st of the same month. Red and black buoys, constructed for the purpose, were placed in position. The bench-marks were renewed. The total length of cut through this bar is 1,552 feet, with a width of 30. The total number of cubic yards removed is 5,100.

Percy's Slough.

The special report of the proposed improvement at this slough, dated February 28, 1874, is herewith appended as part of this report. The appropriation asked, for the fiscal year ending June 30, 1876, will be expended in keeping open the channel of the Lower Willamette and in the necessary repairs to works. A survey will also be made of Willamette Slough, connecting the Willamette at Post-Office Bar with the Columbia at St. Helen's.

Special report of proposed improvement.

UNITED STATES ENGINEER OFFICE,
Portland, Oregon, February 28, 1874.

GENERAL: By your direction a communication from Major Robert, United States Engineers, of November 6, 1873, in regard to the improvement of the bar at the mouth of the Willamette River by the closing of Percy's Slough, near the mouth of the river, was referred to me for revision of the plan of improvement therein suggested and for further information. After a careful study of the reasons assigned by him for the proposed plan of improvement, and upon a thorough personal examination of the locality in question, the following report is respectfully submitted for your information. The project in itself is very reasonable and perfectly practicable, but as to the location of the proposed dam for closing the slough, it appears not to be the proper one, for several reasons which will be enumerated. The inclosed tracing of the map of the junction of the Willamette with the Columbia, showing also the connection between the two rivers through Percy's Slough, will fully exhibit their relative positions. In this proposed improvement it must be borne in mind that the extreme stages or freshets in each of the two rivers occur at entirely different seasons of the year, the interval between the two extremes of water being from four to five months. The last examination made by myself was on the 12th of this month, (February,) at about the average stage of usual high-water in the Willamette, and the tug-boat aboard which the inspection was made was unable to ascend the slough to what may be termed its head, as indicated by the line C D on the sketch. Above that line was an extensive bed of gravel and sand, through which the water could only percolate, if pass at all. Immediately below it was a deep pocket or basin, the soundings showing a depth of water averaging from 7 to 21 feet. This gravel-bar alone, without any additional aid, contains material enough, when set in motion by a strong current, during one of the freshets of

the Columbia, to be able to more than fill the channel at the mouth of the Willamette, when carried into it, held there, and deposited by the opposing currents of the waters of the two rivers. As reported, some 8,000 cubic yards of material accumulate during the freshet of each year, forming the bar at the mouth, and which must be annually removed by dredging, at an expense of $4,000, in order to obtain sufficient depth of water to enable sea-going vessels to ascend to Portland.

Your attention, general, is called to the amount of shipments of wheat and flour alone, and the tonnage of vessels, foreign and home bottoms, to the annexed statement from July, 1870, up to and including January, 1874, as compiled by Mr. Bernard Natoop, of the firm of Roger, Meyer & Co., at my request, and to whom my thanks are justly due for the pains and accuracy with which it has been done. While, according to these figures, each yearly expenditure is more than justified, still more reasonable would it be to apply a few thousand dollars at once for perfecting what may prove to be a permanent improvement; the first-cost of any such work will be saved in the course of a year or two from the amount now required annually to be expended upon keeping a sufficient depth of water upon the bar by dredging. The bar at the mouth of the Willamette will not only be improved, but a good and lasting effect will be had upon what is called Post-Office Bar in the same river; the locality is about four miles above that at the mouth, and its formation is from similar causes. At a high stage of the Columbia River its waters are forced up the Willamette to a short distance above that bar, the counter-currents meeting at that point, and are then discharged back into their original bed through what is termed the Willamette Slough, entering again at St. Helen's, eighteen miles below. A survey of the slough is also recommended with reference to straightening it and removing some ledges of dangerous rocks and snags. A survey of it will be made during the summer, if authorized. Frequently, when the mouth of the Willamette is blocked with ice, the slough can be made available.

The plan proposed for damming Percy's Slough is simply to drive a line of piles of large dimensions across it, to cap them by heavy timber, and to strongly brace them from below; also to cut and throw in, above the row of piles, cuttings from the willow-trees, which can be had on the spot; these will sprout up and grow, thereby forming, in time, a strong obstacle in themselves to the current of the Columbia. The estimated cost of the entire work will be $5,210.26. The location of the dam, as selected by Major Robert, is represented by the lines A B; its length is about 300 yards. The ends of the dam at this point terminate on both sides of the slough in low banks, and, in consequence, a strong current may, during the high-waters of the Columbia, wash them away and form new channels. The location of the dam which in my judgment is the best is the one represented by the line C D; length, about 300 yards. In this position both ends of the dam would abut against high bluff banks on either side of the slough, the most elevated portions of the two islands, (Percy's and Bybee's.) Both these islands would have to be flooded entirely before the water could pass over the dam; an event which is not likely to take place, no incident of the kind being on record. A dam built along C D would not interfere with the boat-landing now used by the planters in the neighborhood, being, as before stated, really at the head of the slough.

The following is the estimated cost of building the pile-dam:

Length, 857 feet; diameter of piles, 15 inches.

686 piles, 15 feet long = 10,290 linear feet, at 6 cents	$617 40
Driving 686 piles, at $2	1,372 00
857 feet capping, 12 by 12 inches, at 12 cents	102 84
Sawing off top of piles and fastening caps, at $1 each	857 00
12,348 pounds strap-iron and spikes, at 14 cents	1,728 72
86 piles for bracing, 20 feet long = 1,720 linear feet, at 6 cents	103 20
Driving and fastening 86 piles, at $5	430 00
Total	5,211 16

Very respectfully, your obedient servant,

N. MICHLER,
Major of Engineers, U. S. A.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

Statement of exports direct to Europe from Portland, Oreg., from July, 1870, up to and including January, 1874.

Month.	Name of vessel.	Tonnage of 2,240 pounds per ton.
July	Herm Doctor	503
September	Alpha	750
October	Choverd	660
November	Fordenskfold	612
December	Lyra	621
December	Mont'y Castle	1,233
Total tons		4,379
1871.		
January	Gungner	693
February	Rosedale	610
March	Tennax Proposeta	604
April	Prince of Wales	637
May	Envoy	782
June	Panama	1,075
September	Skiddaw	1,046
October	Dorenby	1,221
October	Niobe	1,000
October	Bristolian	1,000
November	Alice Graham	660
Total tons		9,326

Month.	Name of vessel.	Total cargo, (tons of 2,240 pounds.)	Lightered, (tons of 2,000 pounds.)	Draught of vessel.
January	Barracoute	908		17
Do	Harrington	815	200	18
February	Metis	870	100	17½
March	Chetah	831	150	18
Do	Coldstream	720	150	16
April	Sparkling Dew	457	150	15
July	A. M. Small	1,350	300	18½
October	Electra	748	200	17½
Do	Navigator	730	200	17½
Do	Manilla	745	200	17½
Do	Loch Dee	1,070	240	17½
November	Siam	951	306	18½
Do	Zouave	1,530	1,000	21½
Do	Ded Deer	983	306	18
Do	Grasmere	1,169	600	20
December	Namorth	528	100	16½
Do	Channel Light	810	220	18
Total		15,215	4,122	
1873.				
January	Victoria Nyanza	1,433	750	19½
Do	Whittington	1,300	600	19
Do	Mendelssohn	1,204	509	20
February	Barracoute	917		17
Do	Roswell Sprague	1,222	418	20
Do	Caribou	1,082	243	18
Do	Sarah Scott	830		17½
Do	Ilione	1,000	350	19
Do	Victoria Cross	951	150	18
March	Penang	764		17
Do	Northumbria	844		17½
Do	Gemini	648		16
April	Tamaya	790		16½
July	Hermene	782		17
August	Confidence	1,052	360	19
Do	Middlesex	1,454	662	21½
Do	Lieut. Maury	546	76	17
September	Otago	1,322	718	20
Do	Privateer	1,251	620	20
Do	Windermere	1,050	466	19
October	Wetterhorn	951	346	18
Do	Theresa Behn	620	136	17
Do	Romeo	937	230	17
Do	Spirit of the Dawn	1,044	385	18
Do	Flecherd	970	200	17½
November	Vesta	541		15½
Do	Lord of the Isles	936	190	17

Month.	Name of vessel.	Total cargo. (tons of 2,240 pounds.)	Lightered. (tons of 2,000 pounds.)	Draught of vessel.
1873.				*Feet.*
November	Gunger	793	225	18
Do	Eskdale	1,802	1,105	20½
Do	Santa Rosa	730	200	17
Do	Fifeshire	1,036	350	18
Do	City of Paris	1,311	708	19
Do	Electra	792	200	17½
December	Cutwater	1,280	800	20½
Do	Allon	994	449	18½
Do	Prof. Airy	612	.....	17
Do	Powhattan	539	.....	16
Do	Discow	1,205	310	18½
Do	Sidlaw	721	.....	17
Total		38,256	11,756	

RECAPITULATION.

Year.	Number of ships.	Cargo in tons of 2,240 lbs., (wheat and flour only.)	Lighterage, (tons of 2,000 pounds.)	Cost of lighterage, (gold coin.)	Remarks.
1870	6	4,379	.....	.....	
1871	11	9,328	.....	.....	
1872	17	15,215	4,122	$6,000	
1873	39	38,256	11,756	17,500	
1874	14	11,120	.....	.....	January.
Total	87	78,298	15,878	23,500	

Shipments by coasters and steamers at 25,000 tons per annum.

LOWER COLUMBIA RIVER, OREGON.

The operations for the fiscal year were confined to the examination and survey of that portion of the river known as the Hogback, lying between Tongue's Point and Woody Island; the observations of the direction and force of the currents; also to determine upon the most eligible plan for dredging a channel. These several works were placed under the charge of Assistant Engineer R. B. Randall, who performed the duties under my instructions. The dredging and buoying of the selected channel were prosecuted with the United States dredger, Mr. D. E. Buchanan in charge. A steam-tug of sufficient power was also employed as a tender to the dredger, and several scows employed in the work. A map of the survey was made, which delineates, as completely as possible, the intricacies of the several channels and the positions of the many shifting sand islands; also a map showing the locality and course of the channel finally determined upon and dredged out; and a map showing the direction and force of the currents. These are all appended as supplementary to this report, and to which reference must be made, as explanatory of the latter. The survey was commenced April 20, and completed by the end of June.

After making a number of soundings, the narrowest place across the Hogback was found to be opposite to the black buoy No. 13, anchored there by the United States Light-House Establishment, and having on it, at the shoalest place, 10½ feet, exactly the same depth as in the channel heretofore used between the upper channel buoy and red buoy No. 10. An examination was then made of what is known as the Johnson Channel. The distance across the Hogback at this place was greater than at the other one, but as the course is more direct, it was believed

that, eventually, it would prove to be the better one. Accordingly the dredger was placed at the west end of the proposed cut. After working four days, it was found that the dipper would not bring up more than one-half of its proper quantity. The cause ascribed for this is, that, in the first place, the compact nature of the sand at the bottom having a tough sedimentary coating, makes it difficult for the dipper to grapple into it; and, in the second place, although the sand was apparently so hard, still, when raised and forced into the dump-scows, would show its characteristic of quicksand by leaking or filtering through the crevices between the jam and gates at the bottom of the hopper. Under these circumstances it was apparent that the mode of dredging employed would have to be abandoned. It was first proposed to use a scraper, to be dragged forwards and backwards by the tug, until a sufficiently deep channel could be obtained. It was then suggested that a large curved hoe, with teeth for raking attached to its lower edge, to be used on ebb-tide, would prove more efficacious. It could be soon made, and at a small cost. When ready for use considerable time had been lost, and the balance of the appropriation available for this work not being large, a change of plan was determined upon. This was, to proceed to work at the original proposed cut, opposite buoy No. 10, this being the shorter of the two, and where scraping could be done to better advantage, with the probability of opening a channel in the least time. The dredger was accordingly moored at the head of this cut, and May 27th work was commenced. At that date the depth was ten and a half feet; by the 24th of June a channel had been scraped down to fourteen and a half feet, which enables a vessel drawing twenty-one feet to pass over the Hogback, at high-water, without risk of touching. The deep-water channel below the cut has been very little affected by the deposits from the scraping. It is believed that the opening now made will continue to widen and deepen through the active and strong pressure of the current passing down Gilman Channel until it again assumes the form shown by the United States Coast-Survey chart of 1870. The *modus operandi* for executing the work, although interesting, need not be here described. As the flood-tides were very weak, the work was carried on the ebb. Upon the completion of the cut an invitation was extended by the engineer of the dredger, on behalf of this office, to all the pilots, both steamer and sailing-vessel, to examine the channel; five accepted, two of the former, and three of the latter, who, after sounding with their own lead-lines, expressed their entire satisfaction in regard to the work; they requested that a beacon be placed upon the sand on the outer side, which would enable them to use the new channel immediately. An iron beacon was planted, which will last for some time, and will serve as a leading-mark. Temporary red and black spar-buoys were also placed, which will answer until the Light-House Establishment replace them by permanent ones.

During the working of the dredger current observations were commenced. These were only noted at the time of ebb-tides, as there is so little flood in the month of June, it cannot have any influence in the formation of shoals. Owing to the great width of the river at Hogback the freshets from the Upper Columbia have no appreciable influence upon the level of the water; the only effect produced by them is to increase the current on the ebb, and retard it on the flood. The tides have their regular rise and fall. The best time for observations of currents would be in October or November, when the upper rivers are low. It is at that period that bars and obstructions are formed, caused by strong flood-tides, and heavy winds with a ground-swell from the sea.

Then the sediment and sand, brought down during the summer and retained in deep channel, are carried back (the salt water having made the particles lighter) to form new obstructions.

The usual appliances were used in obtaining the rate and set of currents; both are fully represented on the map transmitted, and are indicated by figures and arrows. Many of these observations were made during high winds and rough water, for both of which an allowance was made, and, although the results may not be strictly accurate, still they are sufficiently so for the purpose of giving an idea of the action and effects of the currents toward forming the shoals.

From present data no well-devised plan of improvement can be planned; it will be a study of the future. Owing to the great breadth of water it would seem more advisable to let nature work out its own channels, and to then follow them up each year by an economical use of the dredger.

In concluding this report it may be stated that upon the termination of the work the engineer in charge started June 25 with the dredger and scows, in tow of the steam-tug Sedalia, for Portland. After proceeding as far as Kathlamette the current was found too strong to continue along with the entire tow. The dumping-scows were accordingly left there to await the return of the tug. Upon the dredger being moored safely at its old landing near the city, the scows were sent for, and on the way up from Kathlamette the Sedalia took fire and was burned to the water's edge. The scows were subsequently towed up and laid alongside of the dredger. The crew of the latter was discharged upon its arrival.

Financial statement.

Balance in Treasury of United States July 1, 1873:		
Lower Willamette	$10,793 36	
Obstructions	9,206 64	
		$20,000 00
Amount appropriated by act approved June 23, 1874		20,000 00
Amount expended during the fiscal year ending June 30, 1874		14,678 15
Amount available July 1, 1874*		5,321 85
Amount required for the fiscal year ending June 30, 1876		20,000 00

*Of the amount available July 1, 1874, must be deducted $4,800 for building dam across Percy's Slough, which is not yet completed.

Z 2.

IMPROVEMENT OF THE WILLAMETTE RIVER ABOVE OREGON CITY, OREGON.

The report for the fiscal year ending June 30, 1874, for this improvement is respectfully submitted. The operations consisted in the removal of snags and other obstructions, the work continuing until November 8, 1873, at which time the snag-boat was laid up, the appropriation being exhausted.

Commencing at Horseshoe Bend, June 16, 1873, there were removed some large cotton-wood trees, which obstructed the channel very much; thence down the river many serious obstacles were encountered until Bowers's Bar was reached, where several snags were removed and placed in the wing-dam, which had been broken by floating trees and snags the previous winter. At Luckamutte, the renowned "big pine," with its fifty associates, had to be removed. A long time was consumed at this locality on account of these trees being deeply imbedded in the

gravel. Giant-powder was indispensable at this point, as well as at other places. Two hundred and eighty snags were removed during the working-season. Last year the snag-boat failed to remove many snags and stumps, which were removed during the present working-season.

The master reported that the boat did notfail in a single instance to remove every snag, tree, and stump of which it took hold. Many very serious obstacles to the navigation of the river have been removed; many still remain. It is recommended, in addition to the continued removal of snags during the ensuing fiscal year, that certain improvements pertaining to the building of wing-dams be made at the following-named points, should no other process be adopted, together with the removal of rocks at several of them:

LIST.

Polally Bar.	Rocky Rapids.	Magoogalon.
Yamhill Bar.	Long's Crossing.	Half-moon Bend.
Union Bar.	Buena Vista.	Bowers's Slough.
Five Islands Bar.	Wells.	Eola Slough.
Biterman's Bend.	Luckamutte.	Eola Slough Rocks.
Beaver Rapids.	Ferrier's Bar.	Rocky Rapids.
McClosky's Shute.	Fickel's Bars, (upper and lower.)	Humphrey's Rocks.

The average number of feet of wing-dams will be about 6,000. These obstructions extend from Oregon City to Bowers's Slough, a distance of about one hundred and nine miles.

Financial statement.

Balance in Treasury of United States July 1, 1873	$1,500 00
Amount appropriated by act approved June 23, 1874	7,500 00
Amount expended during the fiscal year ending June 30, 1874	1,500 00
Amount required for the fiscal year ending June 30, 1876	25,000 00

Z 3.

IMPROVEMENT OF THE UPPER COLUMBIA RIVER, OREGON.

The appropriation for the improvement of the rapids in the Upper Columbia was exhausted during the working-season of the fiscal year. The following detailed *résumé* of the nature of the obstructions which have been overcome is respectfully submitted. Propositions in regard to the continuance of the work of improvement are also suggested. A personal inspection before and after the completion of the several works, together with valuable information obtained from the river-pilots and the engineer assistant in charge, furnish the data upon which this report is based. The work was done under contract with Mr. J. B. Montgomery, and was superintended by Mr. R. B. Randall, the duly authorized agent of the Government.

Under the direction of my predecessor, Maj. H. M. Robert, the removal of the whole of John Day Rock at the rapids of the same name was accomplished during portions of the months of January, February, and March of the year 1873; also the rocks at the Upper Umatilla Rapids, designated by the letters "Z," "Y," "W," and "X" on the maps previously submitted, were blasted, but the *débris* was not raked off and removed. At the Lower Umatilla Rapid work was commenced during the same period on the rock "E," but it was only partially removed in conse-

quence of the commencement of the annual rise in the river, which necessitated the suspension of all operations for the season. It should be here stated that it is only during the winter-months work can be successfully executed, as at that period the river falls to the very lowest stage, so that many rocks then become exposed above the surface of the water, and the latter becomes clear, thereby enabling the workmen to operate to greater advantage, and thus expedite their labors. Work at that time is somewhat impeded, and often temporarily discontinued, in consequence of floating ice. During the extreme cold weather, however, the thermometer ranging as low as 14° below zero, the river becomes frozen over in a solid mass above and below the rapids, and no interruption then occurs. The laborers soon become habituated to the extreme severity of the temperature, as the weather remains perfectly clear during the greater part of the winter.

Operations on the rapids were not resumed until the 1st of November, 1873, the river by that time having fallen to a suitable depth. The working-scows were then dropped down the river from Umatilla, at which place they had been moored during the summer, to Devil's Bend, a short distance below. At this point a channel was opened 100 feet in width and 600 feet in length; this was done by removing all bowlders or rocks from the gravel-bar above the bend, which lay within 5½ feet of the surface of the water, at which stage it corresponded with the zero-point on the gauge at Umatilla. The boats now employed in running on the Columbia above the Dalles to Wallula, and during the highest stages of the water ascending the Snake River as high as Lewiston, are generally loaded to a depth of between 3½ and 4 feet. As the bowlders are covered with little water, and being scattered promiscuously on the bottom of the river, which at this point spreads out to a great width, nearly 3,000 feet between the lines of low-water mark, they were always more troublesome and dangerous than the rocks below; the latter have comparatively deep water around them, and, their positions being well defined, can be easily avoided.

The operation consisted in anchoring the scows immediately over the rock to be displaced, and the drilling of the necessary holes to receive the tin cartridges filled with giant-powder; the latter were fired by a fuse protected by and fastened to the cylinder containing the powder by a wooden stick. The charge was from three to eight pounds, the cases being about three inches in diameter; the holes were drilled to a suitable size to receive them. Upon the completion of that portion of the work, December 2, there occurred for more than a month a severe freezing spell which caused much floating ice; work was consequently suspended during that time, and the boats moored in a safe cove opposite Umatilla. On the 8th of January of the present year the scows were warped up to the Umatilla Lower Rapid, and operations were resumed on the following day. At this locality only four rocks were removed, a sufficient number to open a channel large enough for the boats now plying on the river; they are designated on the sketch by the letters C, C′, C″, and D. It was deemed advisable not to continue work on the rock E, which had been partially removed during the previous spring, as it seemed probable that by further lowering the water at that point other rocks might become exposed and made dangerous which otherwise are not so at present. Between the point of the reef and the gravel-bank the current has a velocity of twelve miles per hour. The work at the lower rapid was finally completed and accepted by January 28. Within a few days after this date operations were resumed in the high-water channel at the Umatilla Upper Rapid. By reference

to the map it will be seen that what has always been known as the low-water channel, and which has been used up to the present time, is a very long and circuitous one bounded on both sides by reefs and shoal-water.

Experienced pilots can alone navigate it. The one called the "High-water Channel," which hitherto has been used during the season of high-water, and which can now be safely run during the lowest stages of the river in which boats can pass over the rapids between Wallula and the Dalles, has been made a direct and short one. At this rapid such rocks were selected for removal as would most benefit navigation, as only a limited quantity could be displaced in order not to exceed the amount of the appropriation. Its width at the narrowest point is scarcely 40 feet; this, for several reasons, is by no means sufficient, and it is recommended that an increased width be given to it as soon as the necessary funds become available. It is stated, notwithstanding the unevenness of the bottom on the outside of the channel from which the rocks have been removed, that boats ascending with a draught of 4 or even 5 feet of water would experience no danger, but that in descending there would be considerable risk on account of the swiftness of the current, there being danger of a sudden sheer-off and the boats not being perfectly manageable. At the head of the rapid it has a velocity of twelve miles an hour. During a high stage of water the pilots will continue to use it as formerly, and as the river falls will learn by experience whether it is an improvement upon the "Low-water Channel," that on the Washington Territory shore.

To make the high-water channel perfectly safe at every stage of water, it is estimated that it would require the removal of about 100 cubic yards of rock on the south side of the head of the rapid, a like amount from the edge of the reef (at the narrowest point) on the south side of the channel, and a similar quantity, as contained in four rocks, on the north side. This work accomplished, a width of 75 feet would be obtained throughout its entire length; by then using it, steamboats coming down-stream against the strong summer-winds would avoid the trouble and risk often experienced in running the other channel. By February 25 the work was completed so far as the nearly exhausted funds would admit, and its execution by the contractor accepted.

It may not be uninteresting to state the method adopted by the superintendent of the work for sounding the very swift current over the rapids. The scows, four in number, were fastened end to end, and firmly anchored from above the rapids; the entire length thus obtained was equal to 185 feet. A series of soundings, commencing at the head of the channel, was then taken, a long iron rod, graduated to feet and inches, being used; this was plunged well forward in the current so as to obtain as near as practicable a perpendicular position upon striking the bottom of the river. This was done once on each side and along the entire length of the united scows. The latter were then hauled by their boat-lines distances of 18 feet, and new sets of soundings taken until the entire width of the channel was passed over. The scows were then allowed to drop down their own length, and the foregoing operations repeated; this was continuously done until the whole length and breadth of the channel had been accurately sounded. By this method an area of 900 feet by 75 feet was examined. Angles were taken with a sextant at each shift of the boats upon some principal stations, those designated on the map by the letters C, D, and N; these were marked by iron rods set in holes drilled into the rocks for the purpose. These stations were established by triangulation from a base-line of

2,150 feet laid out and carefully measured on the Oregon shore. After the removal of the several rocks and the completion of the work upon those blasted the previous year, a second examination was made of the channel, commencing from its foot. Timbers 6 inches by 6 inches were rigged across the bow of the scows and planked; these projected over the sides so as to present a frontage of 40 feet. The iron rod was then used as before to obtain soundings at intervals of 5 feet, and an accurate section of the channel thus obtained. The boat was then heaved ahead by the hawser a distance of 5 feet, measured upon the latter, and a similar set of soundings obtained; this was continued until the head of the channel was reached. Angles to certain established points were taken with the sextant to locate each successive position of the scow. The top of the rock marked C was adopted by agreement as the level for the low-water mark, and the zero of the water-gauge at Umatilla was made to correspond with the same point.

The following recommendations are made in regard to future operations on the Upper Columbia at the several dangerous rapids which render navigation dangerous. In addition to the improvements previously suggested in regard to the "High-water Channel" of the Umatilla Upper Rapid, the captain and pilot of the steamboat Tenino, Captain Coe, recommends the removal of all the rocks on the north side. To this officer my thanks are justly due for much valuable information concerning the river and the nature of the difficulties to be overcome. He also states that if a channel was made with a uniform depth of 6 feet, and having only one rock left in it with but 5 feet on it, a boat in passing over it will have her headway deadened, the boat seeming to draw towards it; and from this cause arises the great difficulty of steering where there are many of them.

Howly Rapid is similar to the upper part of Devil's Bend. Large bowlders, which have been borne down on drifting ice, are deposited on the bar, and will have to be removed by the same method as was adopted at the last-named locality.

At Squally Hook the rocks marked A and B should be removed. In descending, a boat has to sheer so much across the current to avoid them that her stern is in danger of striking the latter. There is also a small one immediately in the channel, over which boats pass, excepting at the lowest stage of water.

At the Owyhee Rapid the river is both wide and shoal; the bottom is gravel, covered with bowlders. The steamer Yakima struck one of them, and while in a sinking condition was run on a bar below, her deck remaining just above the surface of the water. The improvements suggested for this locality are the establishment of leading-marks on the shores and the removal of all bowlders within 50 feet of the line on each side.

At the foot of Rock Creek Rapid there is a large rock, which should be blasted. In ascending, boats put close to its south side; in descending, owing to the swiftness of the current, they hug close the Washington Territory shore, making quite an elbow to avoid it, and incurring great risk at the same time of running upon others.

Between the Cascades and the Dalles, the shoalest place at the lowest stage of the river had seven feet of water upon it; there are other shoal places, but none are dangerous.

The amount of the appropriation for the current fiscal year, $20,000, will be applied as far as possible toward the improvements above enumerated, so as to make the river from the Dalles to the crossing of the North Pacific Railroad (near the mouth of Snake River) in the same

navigable condition as at the several rapids, John Day, Umatilla, and Devil's Bend.

The quantity of rock removed was 1,425 cubic yards.

Financial statement.

Balance in Treasury of United States July 1, 1873	$9,000 00
Amount in hands of officer and subject to his check	19,183 76
Amount appropriated by act approved June 23, 1874	20,000 00
Amount expended during the fiscal year ending June 30, 1874	28,085 11
Amount available July 1, 1874	98 65
Amount required for the fiscal year ending June 30, 1876	40,000 00

APPENDIX Z 4.

ANNUAL REPORT OF MAJOR HENRY M. ROBERT, CORPS OF ENGINEERS, FOR THE FISCAL YEAR ENDING JUNE 30, 1874.

MILWAUKEE, WIS., *August* 28, 1874.

SIR: I have the honor to submit the following as my annual report on the works of river-improvement in Oregon for part of the fiscal year ending June 30, 1874.

By Special Order 179, War Department, Adjutant-General's Office, dated September 8, 1873, I was ordered to be relieved from this duty by Maj. N. Michler, who took charge of these works on October 22, 1873. Up to that date the work done was as follows:

IMPROVEMENT OF THE LOWER WILLAMETTE AND COLUMBIA RIVERS FROM PORTLAND, OREGON, TO THE SEA.

At the commencement of the fiscal year the steam-dredger (Morris and Cummings's patent 1½-yard bucket) was nearly finished, its completion having been very much delayed by its machinery being detained in San Francisco for payment of full freight-charges.

The great fire of August 2 in Portland, destroying over twenty blocks, caused another delay by the destruction of the foundery in which the steam-capstan for the dredger was being built. She was recalked, as also were the dumping-scows, in August, and was finally finished two or three weeks after the commencement of the long low-water season. She was towed down river September 1 to the mouth of the Willamette, on which bar she began work, dredging a channel 80 feet wide and holding 15 feet at low-water. The work was done under many disadvantages, the engineer and men being new to her pattern, and the bottom very hard till broken; then consisting of fine quicksand, a large portion of which would float away before the bucket reached the scow. Notwithstanding these disadvantages, she removed in 18 working-days of September 36½ scows of 100 cubic yards each.

Several large ships laden with grain, as well as the regular ocean-steamers, passed through the cut during this month, and, the dredging being in progress, necessarily some detention occurred until it had advanced sufficiently to give a temporary channel. The cut was made 40 feet wide across the whole bar, (350 feet,) then a second cut 40 feet wide was made alongside this, and a third cut, 2 feet deeper, in the center of these two, was being made when I turned over the work.

Five spar-buoys, 40 feet long, with sinkers and shackles weighing

over 2,000 pounds each, were placed in position on Swan Island Bar, in place of the old buoys, reported by the pilots as too small to be seen at night.

An examination of Columbia Slough was made by me, and my views as to the stopping of this slough by a pile-dam placed at the *widest* and *shallowest* part were transmitted to the Chief of Engineers in a report dated November 7, 1873, to which I would refer.

Examinations with the lead-line and sextant were made by my assistant over the various bars on the two rivers in advance of the dredger's work, to determine the best line for her to work on. These examinations were made at Swan Island Bar, where no material filling was found, only 4 to 5 inches, and of no great extent, after seven and a half months' intermission of dredging; also at the mouth of the Willamette River, where but 10 feet of water was found, and but 12 feet for a linear distance of 500 feet.

Also at Post-Office Bar, which had but 15½ feet of water on it, and at St. Helen's on the Columbia, where the average water on the line of cut was but 15 feet. The maps and results of these surveys were duly transferred to Major Michler.

A survey and chart was also made, by my assistant, of the "Hog's Back" Bar, in the Columbia River, near Astoria. The result was communicated to the Chief of Engineers in a special report dated November 7, to which I beg to refer.

The amount received and expended by me for this improvement is as follows:

On hand July 1, 1873	$5,118 08
Received since, (of which $5,000 was from the new appropriation for this fiscal year)	7,406 64
Expended:	
New dredger	3,763 10
Stores and supplies	170 81
Watching property	29 41
Repairs	739 03
Dredging	966 20
Towing	800 00
Buoys	1,378 62
Office-expenses, salaries, &c	406 70
Surveys	646 86
Total	8,900 73
Balance transferred to Maj. N. Michler	3,623 99

IMPROVEMENT OF THE UPPER WILLAMETTE RIVER, OREGON.

One hundred and ninety-one snags were removed from the river-bed up to September 30, and the snag-boat crew built 360 feet of dam at Union Bar. Giant powder had to be used on several snags to loosen them and break them up.

Eight small buoys were placed in the river at Tualatin Rocks and Rock Island.

I visited the bars at Union and Yamhill, and found the wing-dams built there last year in good preservation, and answering the purpose they were intended for.

There have been received and expended for this work by me the following sums:

On hand July 1, 1873	$12 21
Received since	3,000 00

nagging	
owing	
tepairs	
tores and supplies	175 64
luoys	67 75
uperintendence, &c	178 71
Office-expenses, salaries, &c	245 57
Total	2,235 43
Balance transferred to Maj. N. Michler	776 78

IMPROVEMENT OF THE UPPER COLUMBIA RIVER, OREGON.

No operations in the field; waiting for low-water.

Amount on hand July 1, 1873, (of which $15,157.50 was due the contractor, but retained till the completion of the entire work)	$19,214 3
Expended:	
Office-expenses	30 5
Balance transferred to Maj. N. Michler	$19,183 7

SURVEYS FOR IMPROVEMENTS OF RIVERS AND HARBORS.—YAMHILL RIVER, OREGON.

I made an examination of this stream in September, to ascertain the nature of any improvement which might be undertaken, and to fix on such parts as would require an instrumental survey.

Expecting the arrival of my successor very soon, it seemed but proper for me to leave for him the responsibility of the survey and report upon his new enterprise, so I took no further steps, except, at his request, to make, on the day I left Oregon, (November 7,) a report to the Chief of Engineers upon the examination I had made.

The amount expended by me on this examination and the preliminary arrangements for the survey was $122.31.

I was also charged with an examination of the mouth of the Coquille River, which was made by Major Michler.

Respectfully submitted.

HENRY M. ROBERT,
Major of Engineers, U. S. A.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers.

Z 5.

COQUILLE RIVER, OREGON.

Report of Major N. Michler, Corps of Engineers.

adjacent country, compiled from different authorities, are inclosed for your information. A profile of the entire length of the canal, as contemplated, is also furnished, in order to exhibit the nature of the cut to be made and of the cubic contents of the material to be removed.

Before proceeding to discuss the canal question, a few remarks are deemed necessary to elucidate the matter. The most natural way to reach the waters of the Pacific Ocean from the Coquille River would be by passing out through its mouth. This would, of course, necessitate the improvement of the latter, which, from the character of the entrance, would prove a very difficult and expensive operation. No survey has as yet been made by this office to ascertain the nature and cost of such an undertaking, but by an examination of the Coast Survey Pilot and Charts, and through information gained from other sources, a correct conclusion can be reached.

"The south point of the entrance to this river is a high bluff headland," a mass of rocks, "while the north point is a long, low, narrow spit of land, overlapping, as it were, the southern head, so that the channel runs parallel with and close under it." The channel still continues to run along the northern shore, and then makes a sudden turn to the south. In passing out or in there is great danger of going upon the rocks. "A short distance off it (the mouth) lie several rocks, but not of sufficient size to lessen the western swell which breaks continually across the bar." It is a very difficult entrance, and is seldom attempted. A rocky reef extends across it, which at low-water is almost bare. Through this an expensive cut will have to be made to render it passable for sea-going vessels. "The widest part of the mouth is less than two hundred yards, after which the river spreads out into a large sheet of shallow water, about two miles long by three-quarters of a mile broad, and bounded by low ground." This basin is not deep enough to accumulate sufficient water at flood-tides, by means of which a strong current could be created to wash out and keep open the channel, which is constantly shifting. Owing to the extreme low shores, they are covered with a few inches of water at the very highest tides. It is reported, at very low tides, the river can be crossed by wading over the bar.

The mouth of the river is fifteen miles from Port Orford, and sixteen from Empire City, on Coos Bay; a ferry is established about half of a mile above it. In the last sixteen or seventeen years not more than the same number of small vessels have crossed over the bar. A small steamer built on the river lately passed out, bound for San Francisco. A high-tide, a smooth sea, no wind, everything favorable at the same time, are requisite in order to insure success. Above the basin the river becomes beautiful; it is from two hundred and fixty to three hundred yards in width, and in appearance like a natural canal. The tide-water now runs up forty miles to the mouth of North Fork; formerly, only a few years ago, it ascended to the junction of the Middle Fork. For this distance the depth of water is very great. The river is navigable for about sixty miles. The facts stated explain the difficulties to be overcome, and the correspondingly large amount of money to be expended, if any contemplated improvement, even at the risk of its remaining a permanent one, should be undertaken to improve the channel at the entrance to the river.

The Coquille River and its branches drain a large tract of mountainous country, the coast range, about nine hundred square miles. Its valley is described as being remarkably rich, some two hundred square miles in area. Already over two hundred farmers cultivate the soil, with the necessary quota of stores, shops, and mills. All kinds of cereals

grow flourishingly, although not as yet much planted; potatoes and fruit (apples and pears) excel; in fact all kinds of esculents can be produced. Most superior and valuable timber profusely covers the land, such as myrtle, (laurel,) maple, white cedar, white ash, alder, fir, spruce, hemlock, and other species, large quantities of which are being destroyed for want of means to transport the lumber to market. Several projects have been considered for obtaining means of transportation by which to forward the wealth of this valley to the commercial points on the coast, and thereby open a fine country to the many emigrants now seeking homes in Oregon. The initiative in the undertaking has been made by the building of a wooden railway over what is called Isthmus Divide, connecting Beaver Slough, a branch of the Coquille River, with the Isthmus Slough, a tributary or arm of Coos Bay. The accompanying map and profile indicate the location of the road. It was built by Judge Gilbert Hall, some four years ago, at a cost of about $8,000 in coin; it is a wooden tram-way, consisting of longitudinal wooden rails laid on rough sleepers, the ravines intersecting the divide being crossed by trestle-bridges; it is little more than one and a half miles in length. The means of transportation over this portage consist of a platform-car, drawn by a mule, and conducted by one man. Small light-draught steamers are run from the different localities on Coos Bay up the Isthmus Slough to Hall's northern landing, where passengers and freight are transferred to the car, and transported over the tram-way to Hall's southern landing, at the head of Beaver Slough. At that point they are placed in canoes or small boats, which descend the latter to the Coquille River, along which they are distributed at different points. The entire distance from the first landing to the river, following the sinuosities of the sloughs, is about six miles. An entire day is consumed in making the trip, about two tons of freight being transported over the route each day. The amount passed over the portage during the year 1873 was about six hundred tons, consisting of a variety of articles, such as merchandise, mining-apparatus, steam-engine and boiler, farming implements, and produce of every description.

The quantity has been yearly on the increase. In this connection, while considering the annual extension of trade from the ordinary consequences of additional and growing settlements on the river, one important fact must be considered—the obtaining for shipment of many thousands of feet of lumber and many hundreds of tons of coal, the former to be found along the valley of the Coquille, and the latter imbedded in the Isthmus Divide within less than a mile of the portage, the production of which alone awaits development when more enlarged means of transportation can be obtained. In place of the very limited kind described as now in use, three several plans have been proposed at different times. The first is the building of a wagon-road, the Coos Bay wagon-road, from the river to the Isthmus Slough. The second is the construction of a narrow-gauge railway between the same points. The third is the digging of a canal to connect the waters now separated by a narrow divide, to enable steamers of small draught to run between the different localities along the river to points on Coos Bay, carrying freight for shipment upon ocean-steamers without breaking bulk *en route*. Surveys have been made of each of the plans, and each has its advocates. The third would seem preferable; by it an uninterrupted line of water-course would be had from the country between the head of navigation and the mouth of the Coquille, a distance of sixty miles, with the present or contemplated wharves at Empire City for sea-going vessels bound in and out of the harbor of Coos Bay. From the point

of departure on the river to that sea-port is about twenty-five miles. A line of steamers already makes regular connections between the latter and San Francisco. The first-cost of building a canal would be the greatest; but then again, in connection with its utility, it would offer an additional outlet to the overcharged waters of the river during the heavy freshets which sometimes occur. These latter, it may be here remarked, would in all probability inundate and seriously damage, owing to the marshy nature of the land upon which they will have to be constructed, any wagon or rail road that may be built to subserve a like purpose as that of the contemplated canal. It must be borne in mind that the greater part of the distance between deep channels of the river and the bay is low, not many feet above the average stage of water in each, as will be seen from the following description of the line of the proposed canal, and as shown on the profile.

The following dimensions are deemed sufficient for all immediate practical purposes: The width of the canal to be 30 feet, and its depth 4 feet below low-water mark at ebb-tide. Commencing at the Coquille, it will at first follow the general course of Beaver Slough. The entrance to the latter will have to be deepened and widened by dredging. The first section of the work, which follows up and continues in the slough 5,280 feet, (one mile,) will also have to be widened and dredged in addition to straightening some of its bends. The second section, 13,200 feet, (2 and a half miles,) will be the first cut of from 10 to 14 feet, and will have to be made through a marsh covered with prairie-grass and thick brush, the course running in a northeasterly direction. The third section is 1,500 feet in length, a cut from 14 to 17 feet through a swamp that overlies a hard soil. The fourth section is through the thickly-timbered isthmus divide, first following up a deep ravine, the continuance of Beaver Slough, the line being parallel to the tram-way; then across the divide proper, intersecting the railway, to the head of a second ravine, and following down the latter, the course again becoming nearly parallel to the road, until the head of the Isthmus Slough is reached. The length of this cut (the fourth) is about 3,000 feet, its depth varying from 12 to 93 feet; the latter is the greatest height of the summit of the divide. The nature of the soil is loam; some soft or loose rock will be encountered, and perhaps coal be discovered. The fifth section, which will finally complete the work, is through marsh for some 4,200 feet, at about an average depth of 9 feet. This cut follows the line of the Isthmus Slough. To recapitulate, the termini of the proposed canal are at Low's place, on the Coquille River, (mouth of Beaver Slough,) and at Aiken's steamboat-landing, at the head of Isthmus Slough, arm of Cross Bay. Its entire length will be 27,180 feet, or about five and one-seventh miles. Owing to the distance being greater from the entrance of the bay to the northern terminus than that from the mouth of the river to the southern one, and in consequence of the different physical formations of the respective localities on the coast, the high-water at flood-tide will not reach the terminal points at the same time, the interval being one hour. No locks, however, are necessary, the bed of the canal being on the same level, unless it may prove desirable to retain the water in the canal at high-tides for some purpose, and to prevent a too rapid current from passing through the cut on the occurrence of freshets, or during the interval of high-tides at the termini. At Aiken's steamboat-landing the depth of water at low-tide is 4 feet; the greatest extreme between the highest and lowest water marks known from actual observation is 10 feet; between average high and low tides there is 5 feet. The Coquille, at mouth of Beaver Slough, is over thirty-four feet in depth at

low-water. The highest water noted, that during the freshet of 1867, was 19 feet above the lowest water gauge; there the main rise and fall of the tide is also about 5 feet. There is scarcely any appreciable difference between the tides at the two ends of the proposed canal.

The cross-sections of the canal will be determined by the natural slope of the soil, which upon the isthmus divide is at an angle of thirty-three degrees, or by the character of the rock that may be encountered. The sides of the cut through the low, marshy soil will have to be protected by sheet-piling from the wash of the tides and the scouring effects of the currents. By a proper disposition of the material removed from the cut many acres of marsh-land may be reclaimed.

The principal nature of the work will be the excavation through the divide; the cutting and removal of timber; the dredging of parts of the two sloughs; the cutting of turf from the surface of marsh, and the clearing off of brush.

The following estimate of the cost of the work is respectfully submitted:

Excavation 769,182 cubic yards, at 35 cents	$269,213 70
Dredging 225,979 cubic yards, at 10 cents	22,597 90
Clearing surface of trees and brush, 40 acres, at $50	2,000 00
Cutting turf and brush from surface of marsh, preparatory to dredging	1,500 00
Sheet-piling, 500,000 feet, at $15 per M	7,500 00
Engineering, transportation, and superintendence	15,000 00
Contingencies, 10 per cent	31,781 16
	349,592 76

The sum total of estimate of cost of construction of proposed canal, as above computed, is $349,592.76.

The survey was commenced and completed during the month of November, 1873. Since that time the maps, estimate, and report have been in course of preparation when not interrupted by attendance upon other duties.

I am, general, very respectfully, your obedient servant,

N. MICHLER,
Major of Engineers, U. S. A.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

APPENDIX AA.

ANNUAL REPORT OF MAJOR G. H. MENDELL, CORPS OF ENGINEERS, FOR THE FISCAL YEAR ENDING JUNE 30, 1874.

UNITED STATES ENGINEER OFFICE,
San Francisco, Cal., July 21, 1874.

GENERAL: I have the honor to submit annual report of operations on breakwater at Wilmington, Cal., and removal of Rincon Rock, San Francisco Harbor, California, for the year ending June 30, 1874.

Very respectfully, your obedient servant,

G. H. MENDELL,
Major of Engineers.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

AA 1-2.

BREAKWATER AT WILMINGTON, CALIFORNIA.

At the close of the last fiscal year the timber-work along the line connecting Deadman's and Rattlesnake Islands was completed, and the portion of the line which was to be built of stone was in course of construction, and about two-thirds of it were completed, leaving a gap of 600 feet yet to be filled.

This work was completed in the past year.

A portion of the timber-line consists of two rows of piling, 10 feet apart, which at the date of the last report stood in 5 feet of water at mean low-tide. This portion has been filled between the piles, to the height of 3 feet above mean low-water, with stone and gravel.

Both sides of this double-piled work, which is 1,000 feet in length, have been ballasted to half tide with stone and gravel, and the same was done on both sides of the single-piled work, for a distance of 2,200 feet.

The object of this ballasting is to protect the timber from the attacks of marine insects.

Two stone jetties have been built in order to contract the width of the channel and to control the action of the current. The effect of these jetties has proved beneficial in deepening the water.

One of these jetties was 600 feet long, and it was built in 5 feet of water and carried to half-tide level. The other jetty was 380 feet long, in 6 feet of water, and it is a few inches above the plane of mean low-water, or about 2 feet above the low-water of spring-tides.

A number of short jetties were built of timber or of stone, or of both, on either side of the timber-work, aggregating 700 feet in length. The purpose of these jetties was to protect the work from the action of undermining currents, and to facilitate the accumulation of sand along the work.

An iron rake weighing about 5,000 pounds was dragged across the bar 26 times in strong ebb-tides. The effect was not equal to anticipation. The fact that there was no steamer available at suitable times, prevented a full and satisfactory solution of the question whether the water could be cheaply deepened by this means.

One of the gaps referred to in previous reports as being fitted with tide-gates was closed during the year, and the timber-work was built to correspond with the other portions.

The accumulation of sand along the line has not been as rapid as was hoped. The sand, however, does accumulate. Along the upper section of the work there is a bank of sand above high-water mark, and more than 100 feet in width, for a distance along the line of 2,500 feet.

During the winter and spring a detailed survey of the lower part of estuary was made by Lieutenant Sears, of the Corps, who has been in immediate charge of the work from its commencement. The object of this survey was to obtain the information necessary to enable an advertisement for completing the channel to be issued. In connection with this survey a series of current-observations was made.

An advertisement was issued calling for proposals for completing the channel. The 30th of April was set to receive proposals. No offer was made. Another call was issued in June, under the instructions of the Department, for dredging by the cubic yard.

Under this call the lowest offer made was 49 cents per cubic yard for dredging and $2.50 per ton of stone removed from the channel. This

offer is considered reasonable, and it has been accepted, subject to the approval of the Chief of Engineers.

This offer, if carried out, will make a channel 200 feet wide and 10 feet deep at mean low-water, at a cost of about $60,000.

There will remain a balance after this expenditure, which it is proposed to lay out in training-walls to guide the current and to maintain the depth which may be secured.

A depth of 10 feet at mean low-water will make 16 feet at spring-tide high-water, and 13 or 14 feet at ordinary high-water.

This depth will enable many of the vessels trading to this point to enter the estuary, and it will dispense with the tedious and expensive system of lighterage which has been in use for the past twenty years.

This result will be particularly gratifying to the people of this neighborhood, and indeed it will be particularly necessary on account of the rapid increase of trade at this and adjoining landings.

The depth of water now is something over 4 feet at mean low-water, which is a gain of more than 2 feet since the work was commenced.

During the year the following amounts of stone and gravel were applied to the work in its different parts:

	Tons.
To jetty No. 1	2,647
To jetty No. 2	1,791
To main line	4,149
To filling double work	2,745
To ballasting timber-line	14,446

Of which 8,473 tons were obtained by days' labor, from Deadman's Island and from the main shore.

The remainder was furnished by different contractors.

The amount expended during the past year was	$71,025 08
The amount available for the year ending June 30, 1875, is	74,621 99

This sum will, so far as can now be foreseen, complete the work according to the original project.

It will be remembered that it has always been expected that the accumulation of sand along the timber-line would in time form a natural bank of a substantial character. When this result arrives the timber-work will have done all that was expected of it. It will have served to guide the current for the interval, and will have been a nucleus—an obstruction to favor the accumulation of the sand. But if this accumulation be too slow, there may be reason for apprehension in that the timber may decay or be destroyed, and the estuary be again exposed to the action of a new channel in the wrong place. If this should happen the old state of affairs will recur, and we shall again have but 2 feet of water at the entrance.

It has already been stated that the sand accumulates slowly.

It is therefore good policy to protect the timber-work more thoroughly than has yet been possible. It ought to be covered when exposed with a riprap of stone.

The sum of $30,000 is asked for this purpose.

Financial statement.

Balance in Treasury of United States July 1, 1873	$145,647 07
Amount expended during the fiscal year ending June 30, 1874	71,025 08
Amount available July 1, 1874	74,621 99
Amount required for the fiscal year ending June 30, 1876	30,000 00

AA 2.

REMOVAL OF RINCON ROCK, SAN FRANCISCO HARBOR, CALIFORNIA.

The bids for the removal of this rock were opened July 1, 1873. They were three, as follows, viz:

1. John N. Risdon proposed to remove the rock to the depth of 24 feet at mean low-water, taking out 4,745 cubic yards of rock for the sum of $43,000.
2. A. W. Vonschmidt proposed to remove the rock to the depth of 20 feet, taking out 1,830 cubic yards for the sum of $45,000.
3. Albert Boschke proposed to remove the rock to 24 feet for $44,800.

Early in July the harbor commissioners of San Francisco made request that further action should be deferred until the question of a re-adjustment of the harbor-lines should be concluded, there being reason to expect that any new front likely to be adopted would pass over or include within its limits the rock which it was proposed to remove. In either case it would be for the advantage of the harbor that the rock should remain undisturbed. This request was acceded to by the Department, but subsequently, on August 21, the instructions which had been given to defer action were rescinded, and it was ordered that a contract be entered into with J. N. Risdon for the removal of the rock to the depth of 24 feet.

The contract was signed on September 4, by which it was stipulated that the work should be completed by March 1, 1874, with a provision for the extension of the time until June 1, 1874, in case the work should be interrupted by the winter storms.

In May, upon application by the contractor, the time for the completion of the work was extended to October 1, 1874. The work was commenced in October, 1873.

To the close of the fiscal year there had been removed 1,650 cubic yards, and there remained 3,100 cubic yards to be excavated and removed.

For this work there has been paid the sum of $6,941.62, 50 per cent. of the contract price being retained until the completion of the work. The mode of doing the work was as follows, viz:

A scaffolding was placed over a part of the rock. It was made by driving piles in rows. The piles were capped, and a loose flooring of plank was laid. From this holes were excavated, first, in the usual manner of blasting by drills handled by three men; afterward, however, the drill was lifted by means of a lever. The power was altogether manual.

The holes were 3 inches in diameter, and they were sunk generally about 2 feet below the required depth, some of them being about 19 feet in depth. They were arranged in quin-cunx order, and were sunk at intervals of 7½ feet. The drill was worked through an iron pipe or tube 4 inches in diameter, with a short tripod at its lower extremity resting upon the rock. The object of this tube was to guide the drill, and to preserve the hole when it was necessary for any purpose to extract the drill.

When the hole was excavated, a gas-pipe was placed in it to preserve it until the time came for loading. The charge was nitro-glycerine, or else dynamite, contained in paper cartridges, or else in a tin cylinder, 2 inches in diameter. The charges were generally fired by fuse, some attempts to apply electricity having failed, probably from a defective arrangement of the wires. One or two lines of charges were exploded at once, the explosions being made practically simultaneous by proper adjustment of the lengths of the fuse. When the rock was broken up the pieces were picked up by a dredger and placed in a scow, to be discharged in deep water. Over a considerable part of the well the depth

of excavation was small, being only 3 or 4 feet in depth. This part of the work was done by surface-blasts of dynamite, contained in tin cylinders, about 10 feet in length and 2 or 3 inches in diameter.

Financial statement.

Balance in Treasury of United States July 1, 1873	$48,500 00
Amount in hands of officer and subject to his check	221 71
Amount expended during the fiscal year ending June 30, 1874	8,147 44
Amount available July 1, 1874	33,632 65

APPENDIX AA 3.

ANNUAL REPORT OF LIEUTENANT-COLONEL B. S. ALEXANDER, CORPS OF ENGINEERS, FOR THE FISCAL YEAR ENDING JUNE 30, 1874.

SAN DIEGO HARBOR, CALIFORNIA.

SAN FRANCISCO, CAL., *July* 14, 1874.

GENERAL: As promised in the closing paragraph of my letter to the Department of the 4th of June last, I have now the honor to submit some further information, going to show that the flood in the San Diego River during the past winter has had the tendency to fill up the harbor of San Diego.

It will be remembered that in January, 1872, I directed Lieutenant Handbury to put down some eight or ten sediment-boxes, 3 feet square, in San Diego Bay.

I quote a paragraph from my instructions to him:

> These (the boxes) may be looked upon as artificial bottoms of little portions of the harbor, which can be taken up from time to time, particularly after floods, and examined. The sediment which they contain should be preserved for examination and comparison with those you will obtain from the source whence they must be derived.

The positions of these boxes are shown on the drawing sent with my letter of May 17, 1872.

These boxes, when placed, were raised a foot or two above the bottom of the bay, so as to leave a current of water beneath them, the object being to catch only the matter held in suspension during a flood, and not that which may be rolled along the bottom by currents.

On the 9th of June last I directed Lieutenant Weeden, then at San Diego, to take up and examine these sediment-boxes, and also to examine the shore-line in the vicinity of the mouth of the San Diego River. I now transmit herewith a copy of his report on this subject, consisting of the report proper, an outline sketch of a part of San Diego Bay, and specimens of the materials found in the boxes and on the bottom of the bay alongside of them.

By superimposing this sketch on the Coast-Survey chart, or on Lieutenant Handbury's map, the position of the boxes will be readily seen.

The sketch shows a considerable filling out of the bay at the mouth of San Diego River, the low-water line having been carried out in one place a distance of nearly 800 feet since 1869, the date of Lieutenant Heuer's survey. All of this has been done during the last winter and spring. It also shows a general shoaling of the water in the bay, just outside of the low-water line.

An examination of the contents of the "sediment boxes" shows that the material in them, as also that found on the bottom of the bay alongside of them, becomes finer as the distance from the mouth of the

river increases. This was to have been expected, for the coarser and heavier materials will naturally settle sooner than the finer.

I think this examination by Lieutenant Weeden fully bears out the idea I expressed in my letter of April 25, 1871, that the San Diego River is gradually filling up San Diego Bay, and, in time, will ruin that harbor, unless steps be taken to preserve it. I quote the closing paragraphs of that letter:

My idea is, that the San Diego River—a turbid stream in times of flood—entering the harbor at A, rolls its sands into the bay, which are, to a great extent, spread out or dissipated by the tidal currents. But the waters of this river, at such times, also carry a large quantity of suspensible matter with them. This suspensible matter makes mud when it is deposited. Now, on the ebb-tide, this suspensible matter will be carried to sea and lost in the ocean, but on the flood-tide it will be carried with the water toward the upper portion of the harbor, where it will be deposited at slack water. Once on the bottom, the quiet waters of this harbor, with no resultant current, will have little power to move it. If I am correct in these conclusions—and it is a matter which can easily be demonstrated one way or the other in times of flood—the San Diego River will, in time, entirely fill up San Diego Harbor, unless its outlet be diverted to the sea through some other channel.

In conclusion, I think that the San Diego River should be turned, so as to empty into False Bay, and to accomplish this object I recommend that Congress be asked to make an appropriation of $80,000 for that purpose.

Very respectfully, your obedient servant,

B. S. ALEXANDER,
Lieut. Col. of Engineers.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

Report of Lieut. John H. Weeden, Corps of Engineers.

SAN FRANCISCO, CAL., *July* 6, 1874.

COLONEL: On the 9th of June, being then at San Diego, Cal., I received from the president of the board of engineers a letter, dated June 5, from which the following extracts are made:

* * * * * * *

"What I want you to do is to take up the ten 'sediment-boxes' which Lieutenant Handbury placed on the bottom of San Diego Bay, and ascertain the amount of sediment which has been deposited in each of them, its character," &c.

* * * * * * *

"I will send Mr. Lewis to assist you. He will take the drawings and notes that were taken when the boxes were placed; also two sextants to determine the position of those that cannot readily be found."

* * * * * * *

Mr. Lewis arrived in San Diego on the morning of the 15th of June, bringing an additional letter of instructions from which the following extract is made:

* * * * * * *

"If any considerable changes have taken place in the shore-line or sand bars about the harbor, I wish you would report them."

* * * * * * *

In accordance with these instructions I have now the honor to submit the following

REPORT.

The "sediment-boxes" referred to are described in Lieutenant (now captain) Handbury's report to the president of the board of engineers for the Pacific coast, dated April 25, 1872. They were about 3 feet square by 10 inches in depth, having an outside ledge upon which the ballast was placed, and standing upon legs from 15 to 20 inches in height. Their positions were determined by sextant angles and compass-bearings to known objects. Captain Handbury also took the precaution of marking their actual positions with small watch-buoys, which, however, were soon carried away by the sea.

Before the arrival of Mr. Lewis I had organized a party and provided boats and apparatus necessary for raising the boxes when found; the search for them was begun upon the afternoon of the 15th and continued with the following results, premising hat th e notation used is the same as that upon Captain Handbury's map:

Boxes Nos. 1, 3, and 4 were known to have gone ashore during the winter of 1872–'73. Box No. 2 could not be found, the references being compass courses to station *d*, which had been destroyed, and to ill-defined natural objects. Stations *a* and *b* had also been destroyed, but were re-established with sufficient accuracy to warrant the assertion that box No. 7 had been removed from its position, as it could not be found. Boxes Nos. 5, 6, 8, 9, and 10 were found, raised, and examined.

Box No. 5 was much decayed, and covered with oysters and marine vegetation. The top of the box was 19 inches above the bottom of the bay, and it contained from 5 to 8 inches of mud and sand, distributed as shown in the section. Specimens of the contents of the box, and of the bottom, at the same place, are submitted, marked V and V*a*, respectively.

Box No. 6 was in better preservation than No. 5, but the general characteristics of it were the same. The specimens of the contents and of the bottom adjacent are marked VI, and VI*a*, respectively. It contained from 4 to 7 inches of earthy matter, distributed, as shown in the section.

Box No. 8 was 14 inches above the bottom, and was so much decayed that it broke after being raised clear of the water. Its contents were distributed as shown in the section, the middle portion of the bottom being bare. The respective specimens from within the box, and the bottom adjacent, are marked VIII and VIII*a*.

Box No. 9 was 22 inches above the bottom, and contained but about half an inch of sand and mud evenly distributed over its bottom. The specimens from within and without are marked IX and IX*a*, respectively.

Box No. 10 was 20 inches above the bottom of the bay, and very much decayed. The middle of its bottom was bare, but there were deposits of 2½, 4, 3, and 3½ inches at the respective corners. Specimens of the contents and of the bottom are marked X and X*a*.

In view of the importance of the question involved, and which was the primary cause of this investigation, viz, whether the harbor of San Diego is shoaling or not, I deemed it advisable to make a resurvey of the low-water line in the vicinity of the mouth of the San Diego River. The work has been plotted, and the results are shown upon the drawing which is submitted herewith.

In addition to the above information, called for by the instructions of the president of the board, I beg leave to submit the following resumé of phenomena, of which I have a personal knowledge.

As the president of the board will remember, I was stationed at San Diego during the past year; a year which, on account of the great rain-fall, presented unusual opportunities for observing the effect of the San Diego River upon the regimen of the harbor. In this report it is not thought necessary to consider the effect of the Sweetwater and Otay (spelled Ohjai on the Coast Survey map) Rivers, which are small streams entering the harbor near its southern or upper end: first, because the injury done by them is very small when compared with that done by the San Diego, and second, because this injury is believed to be irremediable, excepting by dredging, since the harbor presents the only outlet for their overflow.

The first rains of the season fell upon the 11th and 12th of August, 1873, amounting to 1.80 inches. So heavy a rain during the summer-months was a most unusual incident, although not altogether without precedent. The rain-fall of the previous four years having been the minimum known since the occupation of the country, this amount was taken up by the soil, without entering the bed of the river.

By referring to the accompanying table, which is taken from the records of the signal-service observer at San Diego, it will be seen that the rainy season proper began on the 14th of November, between which time and the 22d of the same month 0.77 inch of water fell. The next rain was upon the 4th of December, when there was a fall within the twenty-four hours of 2.52 inches. The rain-fall for the remainder of the month was as follows: On the 5th, 0.43 inch; on the 6th, 0.20 inch; 7th, 0.31 inch; 8th, 1.66 inches; 9th, 0.32 inch; 11th, 0.02 inch. The river reached the mission of San Diego, about seven miles from the harbor, on the morning of the 6th, and emptied into the harbor on the 8th, at the same time partially overflowing the flat between the Bay of San Diego and False Bay. This flow continued for eight days.

At the town of San Diego the rain-fall for January, 1874, was as follows: On the 2d, 0.45 inch; 12th, 0.15 inch; 16th, 0.21 inch; 17th, 0.85 inch; 18th, 1.35 inch; 20th, 0.02 inch; 22d, 0.08 inch.

The river emptied into the harbor for the second time at 2 a. m. on the 18th, passing Old San Diego as a "bore" 3 feet in height, and continued flowing, with a varying volume, from that time until the middle of June. At the time of this second outflow the channel of the river for some miles above its mouth was filled with sand; the water-way was too small to afford an outlet for the flood, and, in consequence, at 10 a. m. of the 18th the whole flat between the main-land and Point Loma was covered, the water crossing the divide and emptying into False Bay, as well as into San Diego Harbor. This condition of affairs continued until the 19th, when the river resumed its natural channel.

It is evident that the comparatively large rain-fall of the 18th could have had no part *in producing* the overflow, as it had not then taken place; it is equally evident that

the volume of water to be discharged on the 19th was as large, if not larger, than that which sought an outlet on the 18th, and yet the river subsided. This result could have been produced in but one way, viz., the scouring out of the river-bed. A few rough soundings, at different points, proved this to have taken place, as a depth of from 6 to 14 feet was found.

My duties in local charge of the construction of the fort at San Diego affording me sufficient leisure, I made a personal examination of both sides of the river at every time, during the season, when there was any change in its regimen. These examinations, about twenty in number, offer cumulative evidence of the most positive nature that large amounts of sand and *débris* were carried into the bay, while the instrumental survey of last month proves conclusively that this *débris* was deposited at the delta of the river and along the adjacent shores.

In conversation with the president of the board, in April last, I stated that at least 300,000 cubic yards had been thus deposited. I am now of the opinion that this was an *under* rather than an *over* estimate.

If other evidence were desirable to prove the immediate and urgent necessity for changing the outlet of the river into False Bay, many collateral facts might be cited. For weeks at a time during the freshets, the whole surface of the bay was covered with river-water, surcharged with suspensible matter, the stratum being so well defined as to afford water suitable for drinking at a mile and a half from the river's mouth. That the process of deposition was going on is proven by the examination of the flats at different points. The sand of the river-bed is peculiar to itself, being brought down from the upper portion of the Mission Valley, and utterly wanting in the lands adjacent to the bay, yet this sand is found at those places about the harbor where eddies are formed by the river and tidal currents.

A review of historical authorities joined with an examination of existing facts affords an additional argument in favor of the proposed improvement. The navigator and explorer, Sebastian Vizcaino, who visited this port in 1602, speaks of False Bay as a good harbor. To-day there is between that bay and the true harbor a flat nearly two miles square, which has evidently been deposited by the river. If this process of delta-formation has been so injurious in the past, what guarantee can there be for the future, excepting the forcing of the river into False Bay? There is no alternative. The river must be turned, or a few years, such as the last, will see the second harbor on the Pacific coast, and the only one, save San Francisco, which is now available for large ships, degraded to a slough, navigable only by vessels of the smallest class.

* * * * * * *

Very respectfully, your obedient servant,

JNO. H. WEEDEN,
First Lieut. Engineers, U. S. A.

Lieut. Col. B. S ALEXANDER,
Corps of Engineers, U. S. A., President Board of Engineers, &c.

Table of rain-fall in San Diego during the winter 1873–'74.

November 1873.	Amount, inches.	December, 1873.	Amount, inches.	January, 1874.	Amount, inches.	February, 1874.	Amount, inches.	March, 1874.	Amount, inches.	April, 1874.	Amount, inches.	May, 1874.	Amount, inches.
14	.06	4	2.52	2	.45	3	.01	2	.10	11	.33	1	.06
18	.07	5	.43	12	.15	11	.76	4	.21	19	.01	8	.21
19	.54	6	.20	16	.21	12	.18	5	.12	20	.01	23	.03
21	.07	7	.31	17	.85	13	.30	6	.05	.....	.....	25	.01
22	.03	8	1.66	18	1.35	14	1.24	7	.02	.....	.....	26	.01
.....	.....	9	.32	20	.02	15	.38	14	.06	.....	.....	.....	.....
.....	.....	11	.02	22	.08	16	.03	15	.26	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	17	.31	16	.28	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	18	.41	17	.07	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	19	.04	29	.03	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	25	.07	.....	.....	.....	.....	.....	.....
.....	0.77	.....	5.46	.....	3.11	.....	3.73	.....	1.20	.....	0.35	.....	0.3

Total = 14.94 inches.

The above table is from the records of the signal-service observer at San Diego, and gives the rain-fall in the town. In previous years, when a rain-gauge was kept in the mountains, the rain-fall there was found to be about three and one-half times greater than that at the bay. This same ratio is presumed, from the testimony of competent judges, to have obtained during the past year.

APPENDIX AA 4.

ANNUAL REPORT OF LIEUTENANT COLONEL C. SEAFORTH STEWART, CORPS OF ENGINEERS, FOR THE FISCAL YEAR ENDING JUNE 30, 1874.

EXAMINATION AT SANTA CRUZ, CALIFORNIA.

SAN FRANCISCO, CAL., *July* 26, 1873.

SIR: By letter from the Office of the Chief of Engineers, dated Washington, D. C., March 19, 1873, I was notified that under the provisions of act of Congress approved March 3, 1873, an examination or survey was to be made at Santa Cruz, Cal., in my district.

As it was found upon inquiry, and by examination of such charts as could be procured, that no change sufficiently great to require a resurvey had probably taken place in this harbor, it was believed an examination would give data upon which to base a project for its improvement. During the month of June, under orders, I went to Santa Cruz, made an examination of the harbor, and now report as follows:

Santa Cruz is situated a short distance inland from the north shore of Monterey Bay, and chiefly on the right bank of the San Lorenzo. This during the dry season is a mere rivulet, but, at times, in the rainy season, bears along a large body of water.

In the town and its vicinity are many manufactories. There are extensive powder-works, some seven or eight tanneries, lime-kilns, saw-mills, soap and glue factories, and a foundery. From statistics furnished me, it would appear that, during the year 1872, about 150,000 kegs of powder, from 90,000 to 95,000 barrels of lime, from 7,000,000 to 8,000,000 feet of lumber, and some 90,000 sides of leather, with other articles, were shipped from the two wharves, the money-value of those exports being estimated at more than $1,100,000 in coin. The imports, including about 1,200 tons of nitrate of soda and 325 of sulphur, are estimated at over $730,000 in value.

There is a weekly line of steamers, that of Goodall, Nelson & Perkins, running to and from San Francisco. Owing to climate, local attractions, sea-bathing, &c., Santa Cruz is quite a resort for strangers.

The harbor lies at the northwest extremity of the Bay of Monterey, and is perhaps one and a half miles in length from east to west, by about three-fourths of a mile from north to south. The holding-ground for vessels is good. The land affords protection from winds, going around by the north, from the west to the south. The harbor is open to winds and seas from the southward. The heaviest seas are said to come in from the south to the south-southwest, during southerly gales, in the winter-months. A breakwater would protect the anchorage from these.

There is forwarded herewith a tracing of the shore-line and soundings of this harbor, obtained from the United States Coast Survey, and on it are sketched the position, plan, and vertical cross-section of such a structure.

The usual entrance would be to the eastward. Should it be found the interval at the west end allows too heavy a sea to pass in, an additional work, some 430 yards in length, might be constructed from Point Santa Cruz to cover this gap.

To make a correct estimate of the cost of such a work is difficult. On this coast materials and labor are high. The tendency of trades unions and legislation has been to increase the cost of both, and to lengthen the time of construction of any important work. Appropriations are not made in a lump, but by yearly installments, and these may be intermitted. Contracts must therefore be limited to these yearly amounts, and cannot be made to the greatest advantage. After the work is begun, changes in currents due to it may cause the formation of shoals, and these may render it necessary to suspend operations for a long time, to ascertain the ultimate character and dimensions of the deposits. In the mean time the unfinished structure may be greatly damaged by the action of storm-waves, thus adding largely to the ultimate cost. For some of these reasons, the Delaware breakwater, to say nothing of any other, was some forty years under construction, and was never built of the intended dimensions. It does not contain one-third of the material required for the one now under consideration. This work, if ever undertaken, may, from like causes, linger on to completion through 75 or 100 years. The foregoing elements of uncertainty have been, as far as practicable, taken into account in determining the following estimate. It is also based on the supposition the breakwater is to be constructed of stone of suitable forms, sizes, and character, and in the general way like works have been in some cases heretofore.

Limestone and granite are to be found within a few miles of Santa Cruz, and granite near Monterey.

In the position given this work, the average depth at mean low-water is 7 fathoms. For a running yard, lengthwise, we have 1,004.8 cubic yards of stone, if we suppose no voids. Considering these, and calling two-thirds solid material, which will perhaps be fair, including what will be required for the ends, and for what may be scattered by storms during the necessarily long period of construction, we get 669.8 cubic yards, or, as one cubic yard will weigh about two tons, 1,339.6 tons for every yard in length. It is thought every ton *in place* will cost about $3 in coin, or $3.45 in legal-tenders. This would give, in the latter, $4,621.62 per running yard. A length of 2,300 yards would then cost $10,629,726. Should the auxiliary construction off Point Santa Cruz be made, it would require about 190,000 tons, or an additional expense of $655,500 in legal-tenders.

The present necessities of commerce, to my mind, do not justify a like expenditure; therefore it is not believed anything can be expended profitably on this work during the next fiscal year.

Santa Cruz is in the collection-district of San Francisco. That city is the nearest port of entry.

The nearest fort is that of Fort Point, at entrance to harbor of San Francisco. The nearest light-house is Santa Cruz light.

The amount of commerce and navigation that would be benefited by the completion of the work is indeterminate.

The amount of revenue collected at San Francisco during the last fiscal year is reported at $8,065,988.21.

For statistical and other information I am indebted to the collector of the port of San Francisco, to Messrs. Davis and Nelson, and Captains Johnson and Hobun, in their employ.

Respectfully submitted.

C. SEAFORTH STEWART,
Lieut. Col. of Engineers.

Brig. Gen. A. A. HUMPHREYS.
Chief of Engineers, U. S. A.

AA 5.

SAN ANTONIO CREEK, SAN FRANCISCO BAY, CALIFORNIA.

Report of the Board of Engineers.

SAN FRANCISCO, CAL., *February* 16, 1874.

GENERAL: The board of officers constituted by Special Orders No. 32, headquarters Corps of Engineers, Washington, D. C., March 24, 1873, for the purpose of making the examination and survey and plan of a harbor for San Antonio Creek, California, provided for in section 2 of the act making appropriations for rivers and harbors, approved March 3, 1873, has the honor to submit the following report:

As a preliminary step to the investigation of this subject, the board caused a map of San Antonio Estuary and Bar, and of San Leandro Bay, to be prepared from the best attainable information.

This map embraces the peninsula between these two bodies of water, the city of Oakland on the north side of San Antonio Estuary, and the marshes and sloughs on the east and south of San Leandro Bay.

The map also shows the depth of water in these two bays, the soundings being referred to the plane of mean low-water, as established by the United States Coast Survey.

The sloping shore is shown, with its depth of water at low-tide, from a point north of the present city of Oakland to a position opposite to the entrance to San Leandro Bay.

The board also caused special surveys to be made:

1st. Of the vicinity of the entrance to San Leandro Bay.

2d. Of a line for a tidal canal, to connect the waters of San Antonio Estuary with those of San Leandro Bay.

Tracings of the map and of the two special surveys, marked No. 1 and No. 2, are inclosed herewith.

The board also caused various borings to be made in order to ascertain the nature of the material with which it will have to deal in executing the suggested improvement of San Antonio Estuary.

Many of these borings are tabulated on the map, and others shown in the sections on that map, and on Nos. 1 and 2.

The board also caused simultaneous tidal observations to be made in San Antonio Estuary and in San Leandro Bay, in order to ascertain if there was a difference in the times of high and low tide in these two bodies of water, or a difference in the elevation of the water above a common 0 for the similar phases of the tides.

The results of these tidal observations are platted on the paper marked 3.

The positions of the two tidal stations are laid down on the map.

These tidal observations show that the water rises a little higher and falls a little lower in San Leandro Bay than it does in San Antonio Estuary; the mean difference in the range of the tides of these two bays being about four-tenths ($\frac{4}{10}$) of a foot.

It will also be observed that the times of high and low water are later in San Leandro Bay than in San Antonio Estuary; the mean difference in time being about one hour.

In considering a "plan of harbor" for San Antonio Estuary, we suppose we are to inquire to what extent this estuary can be developed so as to make it a commercial harbor; the number and character of vessels it could accommodate, if so developed, and the cost of such an enterprise.

After a careful study of our maps and examination of the ground, and all the surrounding circumstances, we have arrived at certain conclusions on these subjects, which we now proceed to state:

The estuary of San Antonio receives the drainage of only a small tract of country to the eastward of the city of Oakland, and having no large stream emptying into it to give a resultant current, it is doubtless slowly filling up by sediment brought into it from the surrounding shores during the rainy season.

The estuary, it will be noticed, spreads out at its upper end, so that it is much wider there than it is lower down.

This upper portion is very shallow, a great part of it being bare at low water.

It is the water, however, which this wide but shallow portion of the estuary holds at high-tide, together with that contained in the sloughs and over the adjacent marshes, which scours out a considerable channel in the narrow portions on the ebb-tide when it becomes concentrated.

An examination of the map will show that off the end of Hibbard's wharf, where the channel is narrow, there is a depth of twenty-two feet of water in one place at low-tide.

Again, at the mouth of the arm of the estuary forming Lake Merritt, where it is again narrow, the depth increases, so that we find twenty-three feet in one place at low-water.

Still again, at the entrance of the estuary and for some distance outside of it, we have a depth of water ranging from twelve to eighteen feet at low-water.

But as we go outside, the water flowing out of the estuary is dispersed over a large area, and the depth gradually diminishes until, at the distance of a little more than a mile from the entrance, a bar is formed, having only about two feet of water over it at low-water.

It is a natural inference, therefore, to conclude that it is the scouring effect of the water flowing out of the estuary which maintains a channel of considerable depth wherever the water-way is sufficiently contracted to develop the necessary velocity of current.

And we are forced to the conclusion that, if the water of the ebb-tide could be confined to a narrow passage from the entrance of the estuary out to deep water of San Francisco Bay, a channel would be scoured out to that bay, the depth of water in such channel becoming greater as the width of the passage diminished.

We speak of the ebb-current as doing this work, because it is a well-known fact, in relation to tidal harbors, that the greater portion of the scour of channels is done by the ebb-tide. The flood-current has comparatively little influence in scouring out a channel, because it is dispersive, while the ebb-current is concentrative.

The greater scouring effect of the ebb-tide is also due, in this case, to the manner in which the tides rise and fall in the bay of San Francisco; commencing at low-water large, the tide rises to high-water small, then falls to low-water small, then rises to high-water large, then falls to low-water large again.

Thus we have two steps to get from low-water large to high-water large, while we have but one step to get back again from high-water large to low-water large. It is the scouring effect of this large ebb-tide which keeps this channel open, and of considerable depth where it is sufficiently contracted.

We may observe that it is the latter portion of the ebb-current which is the most concentrated, and which produces the greatest scouring.

It follows, therefore, that one of the first steps looking to the im-

provement of the entrance to this estuary is to contract the water-way over the bar.

The best method of making this contraction appears to us to be by two parallel training-walls of stone. The positions of these walls, with their proposed sections, are shown in detail on the map.

In order to afford the necessary room for navigation, these walls are placed one thousand feet apart from center to center of walls.

If it be found in time that a narrower passage will be more easily maintained at the necessary depth, the width can be easily and cheaply reduced by short wing-dams run out on one or both sides of the channel.

It will be noticed that the constructions we propose do not rise to the full height of the tide. We place the top of the two walls at the height of four feet above low-water, so that they will be entirely submerged at high-water. This insures that the estuary will be entirely filled by each high-tide, for the last of the flood will run freely over these walls, while the first part of the flood-tide and the last of the ebb-tide—which latter does the principal work of scouring—are guided and confined between the two walls.

Our borings on the bar at the mouth of San Antonio Estuary show that this bar is composed of hard sand to a depth of two or three feet, but below this there is a stratum of mud, soft sand, and broken shells nearly to the depth of the proposed channel of entrance, to be hereafter described; and below this, in places, hard sand is again found. This is a very favorable condition of things for obtaining a channel across or through this bar, either by dredging or by the action of the current when it is confined.

In fact, we believe, for the reasons already given, that in one or two years after these walls are constructed the current would, without other aid, wash out a channel between them of some twelve or fourteen feet in depth at low water, approximating in width and depth to the present channel in the estuary above.

Such a channel would be permanent, and it could be obtained at much less cost than by dredging.

The work that is necessary to be done to convert San Antonio's Estuary into a good harbor for commercial purposes naturally divides itself into three parts:

1. *That connected with the entrance.*
2. *The harbor proper.*
3. *A tidal basin.*

For the sake of easy reference, we have designated these portions on the map herewith by the letters A, B, C.

The entrance A is bounded on the northern and southern sides by the two submerged "training-walls."

The harbor B is to be inclosed on the Oakland and Alameda shores by bulk-heads, either of wood or stone, filled in behind, so that the entire length of these bulk-heads becomes available as wharves. Vessels lying alongside of these wharves will have their keels parallel to the direction of the currents both of flood and ebb-tides.

The tidal basin C is to be excavated to the depth of two feet below low-water, so that its entire tidal area will be available when the wants of commerce will justify the expenditure. Of course this space may also be excavated to any required depth, and surrounded by a bulk-head, thus converting it also into a commercial harbor.

But this tidal basin, C, even when excavated so as to make its entire tidal prism available for scour, will not be large enough to contain a

quantity of water sufficient to open and maintain a wide and deep channel of entrance between the training-walls and in the harbor B.

Rather than incur the heavy expense of dredging out these channels, and the annual cost of maintaining them of the requisite depth, we have sought for a cheaper mode of construction, and one, too, by which the depth of water in the harbor and the approach to it will be preserved without the necessity of constant dredging.

Fortunately, such a plan is almost provided by nature.

If the capacity of the tidal basin C could be greatly increased in size, say, so as to double the present quantity of water flowing into and out of San Antonio Estuary, the escaping water of the ebb-tide in the case supposed would scour out and maintain a channel very much wider and deeper than the present one.

We propose to double the quantity of water flowing into and out of San Antonio Estuary by connecting that estuary with San Leandro Bay by a tidal canal of the proper size to insure the filling and emptying of that bay at each flood and ebb tide. For this purpose a dam across the present mouth of San Leandro Bay will be necessary.

Such a canal and dam are shown in the map herewith.

It will be noticed that this dam is not shown to the full height of high-water. To insure the filling of this bay, we only build the dam to the height of four feet above low-water level, which is the same as the height of the training-walls already described.

The flood-tide when it reaches this height will then flow freely over the proposed dam, and add greatly to the quantity of water entering the bay through the canal.

Of course during the first part of the ebb-tide the water will escape over the top of this dam, but after the water has reached the level of the top of the dam all the remaining water in San Leandro Bay must escape through the canal into San Antonio Estuary.

It is possible that in the future it may be well, in order to add to the scouring effect in San Antonio Estuary, to force all the tidal prism in San Leandro Bay to escape, at least during certain tides, through the canal.

To accomplish this, we have sketched automatic tide-gates on the top of the dam across the entire width of the entrance to San Leandro Bay from shore to shore.

These gates would be so arranged as to let the flood-tide flow freely into the bay, but would close, unless prevented from doing so, the moment of the beginning of the ebb current.

	Cubic feet.
The cubical contents of the tidal prism of San Leandro Bay, as it is at the present time, for a rise and fall of tide of six feet, is equal to....	165,000,000
Of the proposed canal.....	20,000,000
Total additional tidal prism in these two bodies of water.....	185,000,000

The cubical contents of San Antonio Estuary, as it is at present, are 157,000,000 cubic feet.

So we see that, when the whole tidal prism of San Leandro Bay is forced to flow out through the canal into San Antonio Estuary, the quantity of water escaping through that estuary on the ebb-tide would be considerably more than doubled.

Exactly what effect doubling this quantity of water would have in deepening the channel in San Antonio Estuary and the entrance between the two training-walls it is difficult to say or to calculate.

We could apply the usual hydraulic formulas governing the flow of water in such cases to the new condition of things when the whole tidal prism in San Leandro Bay and the proposed canal are forced to pass

through San Antonio Estuary, but we do not think it necessary to encumber this report with them further than to show the result at which we have arrived. To do this, let us examine the circumstances at a single point only—say the mouth of San Antonio Estuary. We will state that—

The area of a cross-section at the mouth of San Antonio Estuary at high-water mark = 12, 302 square feet.
Area at low-water = 5, 012 square feet.

2)17, 314

Mean area.... 8, 657 square feet.

Comparing this mean section with the tidal prism of the estuary, there results for a 6-foot tide a mean velocity of 0.838 foot per second. Now, when the whole quantity of water flowing out of this estuary is more than doubled, as it will be when the tidal prism of San Leandro Bay and the canal are forced through it, the mean velocity of the escaping tide will be fully doubled, and the water will begin to scour for itself a deeper and wider channel, until an equilibrium is established between the strength of the current and the resistance of the particles to be moved. Then the size of the channel will become fixed, and its depth will remain permanent.

Exactly what depth of water would be obtained by the proposed constructions is a question, as we have already observed, which it is impossible to foresee. But as the present depth of water at the point we have chosen for illustration is 14 feet at low water at the present time, and as the material to be removed in order to obtain a deeper channel is generally soft mud, like that on the present bottom and sides of the channel, we think it entirely reasonable to conclude that, when the tidal currents flowing through this channel are fully doubled in volume, the depth of the channel will be increased 18 or 20 feet at low-tide.

The same remarks apply to the depth of water in the entrance between the two training-walls, but with still greater force; for the material to be moved there, except for 2 or 3 feet on the surface, is of the same general character as that in the estuary, and the scouring effect there would vary as the quantities of tide-water that lay above any given section-line.

The order in which this work should be executed would be as follows:

First. Construct the two submerged training-walls, beginning at the shore and carrying them out simultaneously, terminating them about the points indicated on the drawing.

Within a year after these walls shall have been completed, with perhaps a little dredging to break the hard sand on the surface so as to direct the course of the scour downward into the soft material, instead of leaving it spread out over the entire surface of harder material, we are of the opinion that a channel would be scoured out between these walls of some 12 to 14 feet in depth at low-tide. This of itself would be a great advantage to San Francisco and Oakland, as well as to the traveling community generally. For then all ferry-boats, river and bay steamers could pass freely from San Francisco or other points on the bay to wharves at Oakland, instead of landing, as they now do, at the end of a wharf some two miles from shore, and carried thence on cars over a wooden bridge, which, however carefully watched, many persons fear will some day or other be the cause of a serious accident.

As there are now some sixty-seven thousand overland passengers

and two million ferry passengers for Oakland and the neighborhood passing over this long bridge yearly, the importance of the consideration above mentioned will be manifest.

Second. Excavate the canal between San Antonio Estuary and San Leandro Bay.

Third. Construct the dam at the mouth of San Leandro Bay.

Fourth. Excavate the tidal basin C.

Then, after the expiration of one or two years, or when the new tidal prisms have done their work, we will know what excavation will be necessary to enable the largest ships to enter the new harbor, so as to "bring ship and car together."

We proceed to give an approximate estimate of cost for executing this work according to the designs shown in the drawing:

1.—Number of cubic yards of stone in the training-walls	127,200	
Number of cubic yards of stone in the aprons, supposing them to be 20 feet square and 2 feet thick, and placed 100 feet apart between centers	6,650	
Total cubic yards of stone in training-walls	133,850	
Which, at $3 per yard, amounts to		$401,550 00

In this estimate we have diregarded the void spaces between the stones, which will be a liberal allowance for the settlement of the stone in the sand, and for the stone that may be washed away by storms during the construction.

We allow two tons of two thousand (2,000) pounds each to the cubic yard.

We suppose the stone to be obtained at Yerba Buena Island.

Dredging.

To dredge a channel between training-walls 100 feet wide and to a depth of 6 feet below low-water, removing thereby the hard sand on the surface of the bar, 113,300 cubic yards, at 30 cents per cubic yard		33,990 00
		435,540 00
Add 10 per cent. for contingencies		43,554 00
		479,094 00

2.—*Excavation of canal.*

Number of cubic yards of excavation in the canal to give a depth of 8 feet of water at low-tide from San Antonio Estuary to San Leandro Bay 2,329,980, at 15 cents per cubic yard	$349,497 00

We have put the estimate for the excavation of the canal at a low figure, because we suppose the excavated material can be used for filling up the marshes in the rear of the bulk-heads at Oakland and Alameda, and that whoever makes this excavation will also fill in these marshes.

The same remarks apply, though to a less extent, to our estimate for the dredging.

3.—*Dam.*

At the mouth of San Leandro Bay. Number of cubic yards of stone in the dam, 21,670, at $3 per cubic yard	65,010 00

4.—*Tidal Basin C.*

Number of cubic yards of excavation to give a depth of 2 feet below low-water, 3,198,100, at 25 cents per cubic yard		799,525 00
		1,214,032 00
Add 10 per cent. for contingencies		121,403 20
Total cost of Nos. 2, 3, and 4		1,335,435 20

At this point our estimate ends. We suppose, if the United States undertakes the improvement of San Antonio Estuary it will confine its efforts to making the harbor accessible for the usual sea-going vessels, and to securing the natural forces of conservation by providing the maximum available tidal areas.

This done, whatever shall remain in the way of providing conveniences and accommodations for commerce, may, we think, with propriety, be left to the commercial interests concerned.

Possibly some future work may be required to obtain the necessary depth of water between the two training-walls. This may be done at first, as we have stated above, by short wing-walls thrown out on either side of the channel, thereby confining the water-way to a width sufficient to maintain the requisite depth.

As commerce increases, the ends of these wing-walls can be taken up, and the width of the channel of approach increased from time to time, if necessary, by dredging.

Here we ought to state, that if our only object had been to provide a narrow and deep channel of entrance to San Antonio Estuary, we would have placed the training-walls only about 500 feet apart; but looking to the probable future wants of this harbor when its commerce may be large, we thought it best to provide a wider entrance.

When the work we have described is completed, Oakland and Alameda will have a fine land-locked harbor or basin at B, capable of accommodating forty large ships at the same time alongside their wharves, with room for as many more at anchor in the estuary, and have room besides for as many ferry-slips as would be wanted to accommodate travel.

Oakland is not a port of entry, the nearest port being San Francisco, distant about five miles. Oakland is so intimately connected with San Francisco that the interests of the two cities, if not identical, are as nearly allied as those of New York and Brooklyn.

We learn from the newspapers of the day that there were 67,000 overland passengers, 2,000,000 ferry passengers, $32,000,000 in treasure from the mines of California and Nevada; 450,000 tons of general freight; 161,000 tons of wheat, valued at $6,440,000, all passing over the long-wharf at Oakland during the past year.

As both travel and trade between the two cities are increasing rapidly, and the present wharf is only a temporary one, it would seem that the interests of the two cities would be greatly increased by some more permanent landings at Oakland.

If such be the views of Congress, and if it be decided to improve the harbor of Oakland, we recommend the appropriation of the amount necessary to construct the two training-walls, and dredge out a channel between them 100 feet wide, having a depth of 6 feet at low-water, at the present session of Congress, viz, $479,094.

This amount would give a beneficial and useful result at once, and establish all the travel and much of the trade between the two cities on a better basis of communication than they now have.

We will close this report by stating that there are many details connected with this improvement into which we cannot enter without prolonging this paper to unreasonable length; such, for instance, as the objections which may be urged against closing up the natural entrance into San Leandro Bay, and to what extent these objections may be compensated by affording a deeper entrance to it through San Antonio estuary and the canal; such, also, as the objection to placing obstructions in the tidal prism of the Bay of San Francisco, and how far this

objection may be compensated by increased tidal water in San Antonio estuary and the canal connecting it with San Leandro Bay.

Again, there will be land-damages, and bridges will be required over the proposed canal.

Still, again, the two bridges across the harbor at Oakland will not be suitable structures when that harbor has an active commerce.

As the first work to be done will be to build the training-walls and dredge a channel between them, time will be afforded during the execution of this work to mature the details of all such special matters not herein discussed.

Respectfully submitted.

G. H. MENDELL,
Major of Engineers.
C. SEAFORTH STEWART,
Lieut. Col. of Engineers.
B. S. ALEXANDER,
Lieut. Col. of Engineers.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

APPENDIX BB.

ANNUAL REPORT OF COLONEL O. E. BABCOCK, CORPS OF ENGINEERS, FOR THE FISCAL YEAR ENDING JUNE 30, 1874.

OFFICE OF PUBLIC BUILDINGS AND GROUNDS,
Washington, D. C., October 7, 1874.

GENERAL: I have the honor to submit the following report of the operations on the works under my charge for the fiscal year ending June 30, 1874:

CARE AND IMPROVEMENT OF THE PUBLIC GROUNDS.—GROUNDS SOUTH OF THE EXECUTIVE MANSION.

The work of filling these grounds to the grade of Fifteenth and Seventeenth streets has progressed as gradually during the year as the appropriation made for the purpose would allow. A considerable quantity of earth is deposited in these grounds by citizens from excavations made from cellars, &c. This, together with such earth as was satisfactorily purchased, was used in grading these grounds.

MONUMENT GROUNDS.

Work was commenced on the Monument grounds July 1, 1873, and carried forward until the appropriation for the same was expended, with the following results: The high ground along Fourteenth street and south of the present roadway was cut down to the proper grade, the earth so removed being used for filling along Fourteenth street north of the entrance of the roadway to these grounds. The graded grounds were rolled, covered with good soil, and sown with Kentucky blue-grass seed. The main roadway was repaired and regraveled, from time to time, in places where needed, and thus kept in good order. Believing it more economical and expeditious to form a small lake of

that portion of the marsh lying east of "Meridian avenue," than to fill the same with earth, a portion of the muck deposited was excavated and removed to the White Lot, and used to form a compost for the dressing of the different grounds. This excavation was completed in September, connection was made with the sewer in B street, and so arranged with stop-plank that at low tide the water can be drawn from the lake. Bountiful springs were found near the shore of the lake, but to insure a full supply of water, the Potomac water was taken from Fourteenth street supply-pipe. This was accomplished by laying 800 feet of 4-inch pipe from Fourteenth street, to a position nearly opposite the Monument, from which point a 3-inch pipe (three hundred feet) was laid to the center of the lake, to which a fountain-jet was attached. During cold weather the lake formed safe and good skating for children, and was much enjoyed by them.

SMITHSONIAN GROUNDS.

As the entire portion of these grounds south, and a portion of them north of the Institute along Twelfth street, had not been graded or improved, work was first commenced there. This portion was thoroughly subdrained, 3-inch tile being used, and laid in trenches 3 feet deep and 30 feet apart. These tiles were led into 6-inch sewer-pipes, which were connected with the main sewers of the city in Seventh and Twelfth streets. The entire grounds above mentioned were graded, covered with good soil, and sown with Kentucky blue-grass seed. As the part of the ground so graded is about one-third of the entire square it required the moving of a great number of cubic yards of earth. It is now ready for the construction of the walks and for planting. A line of 6-inch sewer-pipe was laid along the north line of these grounds from Twelfth to Seventh streets, and connected with the main sewer of the city at the last named street. T-pieces were put in at proper distances to receive lateral drains from the ground formerly occupied by the old canal, which is now a part of these gounds. The gravel walk leading from the Institute north to Tenth street was taken up and relaid with asphalt. This walk is the most used by the public, and after rains, and in the spring of the year, was at times almost impassable. It is now in good condition at all times of the year.

A 13-inch water-main, running through these grounds, was tapped near the center of the grounds and a 4-inch pipe run east to Seventh street. From this pipe lateral branches of 2-inch pipe were run to B street south, 200 feet apart, and stop-cocks and valves were put in at proper distances to afford easy irrigation when needed. The 4-inch pipe was connected with the sewer in Seventh street with a stop-cock, so that the water can be drawn from the pipes in winter when they are not in use, in order to prevent their being destroyed by the freezing of the water. When making connection with the 13-inch main a 6-inch pipe was laid west a few feet, thus obviating the necessity of again making a connection to this main to supply fountains, if it should subsequently be decided to build them. The line of wood fence on Seventh and Twelfth streets was removed, the material of any value being taken to the Monument grounds and stored. The roadways and walks in the improved portion of these grounds have been kept free from weeds, and the trees have been properly trimmed and are in good condition.

ARMORY SQUARE.

In this square the grading has been completed with the exception of a small portion near the railroad depot. The portion graded was

covered with good soil, and sown with blue grass-seed, harrowed in and rolled. The old fences surrounding it were removed and taken to the Monument grounds, and a row of hedge along the line of the old canal was removed, thus giving this square a better and much more extended appearance. The surplus earth taken from these grounds was used in filling the reservations just opposite. As the brick building in this square known as the "Armory building" is old, unsightly, and contracts the appearance of these grounds, I recommend that authority be given to sell the same at public auction, the proceeds to be used in ornamenting the grounds. For this reason I have not included any sum for their improvement in my estimates for the next fiscal year.

RESERVATIONS BETWEEN THIRD AND SIXTH STREETS.

The board of public works having raised the grade of Missouri and Maine avenues several feet, these reservations are so far below grade that they became nuisances from the fact of their collecting the drainage from the higher grounds around, forming pools of stagnant water very injurious to the public health. In order to correct this as far as possible, the appropriation for these reservations was expended for earth to fill in the low places.

JUDICIARY SQUARE.

The old wooden buildings on this square, formerly occupied by the Government as hospitals, and later by the Women's Christian Association, were sold August 12, 1873, but were not entirely removed until November, at which time the improvement of the square was commenced, the subdrainage being the first work done. A brick sewer runs diagonally through this square from G and Fifth streets to E and Fourth streets, built for the purpose of draining the jail, the City-hall building, and for other purposes. Connection was made with this sewer at G street, from which a line of 6-inch terra-cotta pipe was laid alon the north line of the square to the fence surrounding the jail. From this pipe lines of 3-inch tile were laid 3 feet deep and 30 feet apart, and running to Louisiana avenue. From the connection at E street a 6-inch terra-cotta pipe was run west 270 feet; into this lines of 3-inch tile, 30 feet apart, were run south to Louisiana avenue and north to the jail-yard fence. The 3-inch tile was laid 3 feet deep and the 6-inch sewer at a depth to secure the necessary fall to insure rapid drainage. In the construction of this subdrainage 652 feet of 6-inch sewer-pipe and 23,115 feet of 3-inch tile were used. For the purposes of irrigation, and to supply fountains, three lines of 4-inch water-pipe, each 630 feet long, were led into this square from Fifth street; along each one of these lines, at intervals of 200 feet, a line of 2-inch pipe was laid on each side 100 feet from the main line and at right angles to it, at the end of which angle-valves are to be attached, so that every part of the ground, except what is occupied by the jail, can be thoroughly irrigated by using a hose 75 feet in length. To accomplish this, 1,890 feet of 4-inch and 2,200 feet of 2-inch cast-iron pipe was used. A large quantity of earth was hauled into these grounds by the board of public works, which was used in grading the low places. The entire grounds were rough-graded, and part of the walks staked out in readiness for excavation. Large quantities of loose stones were plowed up while the grading was going on. They were collected, together with a lot of other loose stone in the square, and deposited in piles near the jail-yard. They will be broken

to the proper size and used for foundations for the roads and walks. The iron fence surrounding part of the square was turned over to the board of public works, which, together with some of the same pattern taken from around the Capitol grounds, will be used to fence along the line of Government reservation fronting upon the old canal from Sixth street west to Fifteenth street. The brick building on this square, used for school purposes, was removed in the fall. Iron park-posts have been placed in position around the square, and lamp-posts of a corresponding pattern have been substituted for the city lamp-posts; and being placed in line with the park-posts, and having the chain attached to them, the whole line of posts presents a uniform appearance. For the purpose of thoroughly lighting the inside of this square, the necessary mains have been laid, sufficient to supply forty lamps. These posts, three of which combine a drinking fountain, with the requisite number of lamps, have been purchased, and will be placed in position as soon as possible. For the convenience of the people who pass through this square a wooden walk was laid along the line of E street, so as to avoid the mud and wet of the winter and spring.

LINCOLN SQUARE.

In this square the work of excavating, grading, graveling, and rolling the walks has been completed, 5,383 square yards of walks having been constructed. Two fountain-bowls, each 30 feet in diameter, have been made of brick, and the necessary supply of water and drain pipes led into them. A lodge, similar to the one in Franklin Square, with urinals on each side, has been erected, and the necessary connections with water and sewer pipes made. The lodge is ornamental, and its accommodations of much value to the public, and prevents the committing of nuisances. The trees have been properly attended to, being trimmed when required, and are in good condition.

SCOTT STATUE RESERVATIONS.

The reservations on each side of the Scott statue have been graded, soiled, seeded, and inclosed with posts and chain. They have also been ornamented by the planting of trees, evergreens, &c. The circle grounds immediately surrounding the statue have also been improved by being graded, soiled, and sodded, and planted with ornamental and flowering plants, evergreens, &c. A stone curb has been set around the circle inside of the stone flagging, next to which a brick gutter has been laid for the purpose of carrying off the surface-water from the mound, which would otherwise run on the pavement. This gutter has been connected with the main sewer on Sixteenth street.

The water-pipe running through the circle has been tapped in two places, and 1¼-inch angle-valves attached. The taps were made near the circumference of the circle, and opposite the reservations on either side, so that they can be easily irrigated if necessary. Four lamp-posts and lamps have been placed around this circle, and all necessary connections made with the gas-mains.

RAWLINS SQUARE.

This square has been inclosed with an iron post and chain fence, and lamp-posts of a pattern corresponding with the park-posts have been placed in position around the square, thereby affording sufficient

light, and both lamp and park posts have received two coats of paint. To prevent washing, a small terrace was made and sodded along the north side of the square. The square was sown with blue-grass seed, which has taken well, and will make a good lawn. The following is the number and variety of the trees planted in this square: 6 juniper, 8 Virginia cedars, 4 dogwood, 1 sassafras, 1 black-walnut, 3 English maples, 3 spireas, 1 magnolia, 4 forsythias, 1 birch, 1 Japan quince, and 1 jasmine. These trees were transplanted during the winter, when the ground was frozen, and were removed without disturbing the earth around their roots.

CIRCLE RHODE ISLAND AND VERMONT AVENUES.

At the date of my last annual report this circle, the largest in the city, had been partially subdrained, and water and gas mains led into it. At that time the sewer along Rhode Island avenue into which this sewerage was to be led had not been built. This sewer was completed by the board of public works during the spring, and connection was made with it and the circle drained of the ponds of stagnant water, after which the improvements were renewed. The circle was graded, excavation for fountain made, drainage for the same provided, connection made with the water-pipes for supplying the fountain, and the work of constructing the bowl commenced. A quantity of clay from this circle was hauled to the "Scott Statue reservations," and used in grading the same.

WASHINGTON CIRCLE.

This circle has been improved by taking up the gravel walks, grading and narrowing them, and relaying the screened gravel. They were carefully rolled, and now present a smooth and hard surface very pleasant to walk upon. The ground around the statue has been enlarged, regraded, and sodded. A brick gutter was laid around the circle inclosing the statue and on each side of the walks, the former being led into a trap located north of the statue. From this trap a line of 4-inch sewer-pipe was laid to the main sewer in New Hampshire avenue. This will collect the surface-water from the mound, and thus prevent the washing of the walks. The 12-inch Government water-main that passes through this circle was tapped and two angle-valves attached. They were placed near the circumference of the circle surrounding the statue for the purpose of affording easy irrigation, if needed. The portion of these grounds that was regraded was sodded; the trees were trimmed to open a view of the statue, and the seats replaced and fastened in position.

RESERVATION NO. 17.

The appropriation for this reservation was expended in grading and getting out gravel for roadways, walks, &c. The condition of the ground was such that but little progress could be made with the small amount appropriated. The remains of the stone foundation for the jail building are still on these grounds.

TRIANGULAR RESERVATIONS.

Two reservations on Massachusetts avenue, between Tenth and Twelfth streets, which were above the grade of the avenue at that point, as established by the board of public works, were cut down to

grade, and the dirt, 2,951 yards, was hauled into the grounds south of the Executive Mansion, and used for filling.

Four reservations on Pennsylvania avenue, east of the Capitol, were surrounded with iron posts, to which was attached a rail of gas-pipe. The reservation on Massachusetts avenue, between Fifth and Sixth streets, named "Ashland Place," in honor of Henry Clay, has been graded, water and sewer pipe led into it for a fountain, and inclosed with a wrought-iron fence.

The reservation on New York avenue, between Tenth and Eleventh streets, has been inclosed with a wrought-iron park fence, and a fountain and iron bowl also placed in position, for which the necessary water and drain has been provided. A number of evergreens has been set out in the reservation on New York avenue and H street, in front of the Presbyterian church at that point.

The reservation on the north side of Pennsylvania avenue between Eighteenth and Nineteenth streets has been improved by removing the old wooden fence that inclosed it and substituting a park post and chain. It was graded and the walks laid out on the same plan as the one opposite. The walks were filled with gravel and rolled. A few park settees were placed in this and the reservation opposite and securely fastened to the ground.

CONGRESSIONAL CEMETERY.

No work has been done in this cemetery since my last annual report, except to grade and sod the slope of H street, which was widened last year. This was found necessary to prevent the grade from being destroyed by rains. The amount appropriated for this cemetery was thus exhausted.

MANURE.

A large number of cart-loads of a vegetable deposit (muck) has been excavated from the low and marshy grounds in the Monument Lot and hauled into the White Lot adjoining. This muck after being exposed to the action of the weather was turned over and thoroughly mixed with lime, 1,500 bushels of which were used. The lime pulverizes the muck and kills the germ of any seed that may be in it, and makes a valuable and comparatively cheap compost. It was hauled and spread on the public grounds when they were frozen, to prevent the cart-wheels from damaging the sod. The grounds were raked after spreading so as to evenly distribute it. The use of this compost has been very satisfactory and the growth of grass marked.

PROPAGATING GARDEN.

The green-houses at this garden, formerly located on reservation corner of Third street and Missouri avenue, were removed to the Nursery grounds, Reservation No. 3, and extensive additions were made to them. The material used in rebuilding these houses was taken principally from the old green-houses and from the houses removed from the squares added to the Capitol grounds last year. In addition to the construction of these houses two rows of frames were built and supplied with the necessary heat, &c. These frames are comparatively inexpensive to build and heat, and are very useful. The plants were removed to the new houses and properly arranged before any damage was done to them by frost or exposure to the autumn storms. A quantity of bulbs and

seeds was imported from Europe for the green-house and the grounds, and was imported to secure the varieties desired. A portion of these seeds, together with others saved from the public grounds, were properly put up in papers, labeled, &c., and one package containing sixty papers was delivered to each member of Congress. In addition to this distribution of seeds every member who applied was supplied with fifty cuttings of various green-house plants, &c., of the surplus stock of such plants in the green-houses. Most of these plants were packed in boxes ready for shipment.

NURSERY.

The Nursery grounds were inclosed with a wooden fence, the old palings taken from the various reservations being used for that purpose. It was not the intention when these grounds were first selected as a nursery to inclose them; but it was found that the young stock could not be properly protected without it. A quantity of such stock as was deemed advisable to be set out in the public grounds for their embellishment was purchased and placed in the nursery, to be used from time to time as occasion may require. In addition to the stock purchased, a large amount of seed was gathered from the trees in the public grounds, selecting only such varieties as are most desirable, and was planted in the nursery. There are now several thousand young trees from this planting, which with proper care will in a few years furnish such trees as will be needed in the public grounds.

TREES, EVERGREENS, ETC.

During the winter, when the ground was frozen, a number of large trees was transplanted from the White Lot and other reservations. They were of the following varieties, and were distributed in the reservations as follows:

Scott Square.—Two elms, 2 forsythias, 1 catalpa, 2 spireas, 13 enonymus.

Farragut Square.—Three English maples, 2 elms, 2 horse-chestnuts, 3 Norway maples, 1 enonymus.

Mount Vernon Square.—One white ash, 1 persimmon, 15 elms, 14 maples.

Circle Massachusetts, Connecticut, and New Hampshire avenues.—One ash, 1 ash-leaved maple, 1 sycamore, 1 sugar maple, 4 cedars.

These, together with those placed in Rawlins Square already enumerated, make 110 trees so removed.

In the spring the landscape gardener, by my direction, visited nurseries in Pennsylvania, New York, and New Jersey, and purchased a number of fine specimens of trees, evergreens, &c., such as could not be purchased in this vicinity. They arrived in good order, and were placed temporarily in the nursery. Some 600 of these were transplanted, being placed principally in Scott, Farragut, Franklin, and Rawlins Squares, and Mount Vernon Place. Nearly all have grown well during the summer.

FOUNTAINS.

The various fountains have had proper care and attention. In the fall the water was turned off and the bowls filled with leaves to prevent their being damaged by frost. In the spring the leaves were removed and the water turned on, and it was found that the bowls had sustained no injury from the frost during the winter. Much annoyance is experi-

enced in the spring from fish spawn that gets into the jets of the fountains and prevents the free play of the water.

CHAIN BRIDGE.

At the date of the last annual report the rebuilding of Chain Bridge was under contract with Mr. S. R. Dickson, of New Haven, Conn. By the terms of his contract the bridge should have been fully completed by the 1st day of June, 1873. He was repeatedly notified to commence and finish his work, and on the 15th of October, 1873, (there being no evidence that he had even commenced it,) he was finally notified that his contract was annulled.

With the approval of the Chief of Engineers, a contract was then entered into with Messrs. Clark, Reeves & Co., of the Phœnixville Bridge Works. Their contract was dated November 14, 1873, to be fully completed on or before the 1st of May, 1874. They immediately commenced the work, and their first shipment of iron was received December 26, 1873; other shipments followed in rapid succession, and the entire work was fully completed on the 27th day of March, 1874.

It is due to Mr. Dickson to state that the several communications sent to him from this office to the address given by him were not received by him, but were returned to me by the postmaster of New Haven, the 10th of January, 1874.

SCOTT STATUE.

Since my last annual report the granite pedestal for the Scott statue has been received and placed in position, on the site selected for the same, at the intersection of Rhode Island and Massachusetts avenues. The largest stone, weighing 119 tons 1,171 pounds, was removed from the foot of G street northwest, in eight days, without damage to either the stone or the roadways over which it was moved. The bronze statue was placed in position as soon as the pedestal was ready to receive it.

MISCELLANEOUS.

The post and chain inclosing Farragut Square, and the iron fence inclosing the triangular reservation on Pennsylvania Avenue between Twentieth and Twenty-first streets and the Washington Circle, was painted. The rustic seats in the Fourteenth-street Circle were repaired, scraped, and varnished. The other seats in the public squares that were torn from their fastenings during the winter, were repaired, placed in position, and fastened. A large number of cocoons of the basket caterpillar were picked from the evergreens and destroyed, thus preventing an immense amount of damage being done them. These worms are very injurious to evergreens, and in a very short time will destroy them if not removed.

The snow and ice were promptly removed from the walks along the public reservations under my charge. Three hundred and fifty boxes for the sparrows were made by the carpenters during the winter, and in the spring were securely fastened to the trees.

The increase of the sparrows has been so rapid that all the boxes were occupied almost immediately. They have not been so much disturbed by the boys this year, in consequence of which they are becoming more tame.

Much annoyance is experienced with the wild garlic which grows in most of the public reservations. Large quantities have been dug up

and removed, especially from Lafayette and Franklin Squares and the grounds around the Executive Mansion.

The President presented to this office a handsome specimen of an American eagle, which had been sent to him from Wisconsin. A cage was constructed for it and placed in Franklin Square, thus adding to this square a feature of much interest to the children of the city. Specimens of animals are frequently offered to this office from officials of the Government and private individuals, which are often declined for the want of means to properly house and care for them. In a few years, and at a comparatively small expense, a very fine collection of American and other animals could be collected. Such a collection would be a great source of entertainment to the people of the capital and those visiting it, besides being of great value to the student of natural history.

I would respectfully recommend that an appropriation be made to provide for receiving such contributions.

The trees, evergreens, &c., in the various reservations have been cared for and properly trimmed in season. Some of the evergreens were tied up to prevent the breaking of their branches from the weight of snow falling on them during the winter. While the leaves are falling a force is employed to collect and remove them. They are deposited in piles, thus forming a vegetable mold which is very valuable, and which is used in the green-houses for propagating purposes. What is not used for this purpose is used for top-dressing for lawns.

The electrical lighting apparatus in the Capitol has been kept in thorough repair. No trouble has been at any time experienced in working it.

By a careful supervision of the consumption of the gas in the entire Capitol building during the long session of Congress, a great saving has been effected, enabling a return to the Treasury of the United States of the sum of $10,257.62 of the "lighting fund."

The triangular reservation on Seventh street and Pennsylvania avenue, which was opened to the public in June, 1871, has been closed, the abuse of the privilege more than counterbalancing the benefits to the public.

The public gardener has been employed during the year, when his services were not otherwise required, in preparing maps of the reservations that had been improved by this office. These maps give the roadways and walks, locate the fountains, drinking-fountains, and the drains, and gas and water pipes. Maps of the following-named reservations have been so prepared, viz: Lafayette, Lincoln, Judiciary, Scott, and Farragut Squares, Washington and Thirteenth-street Circles, and the circle at intersection of Massachusetts, Connecticut, and New Hampshire avenues, and Mount Vernon Place, the grounds around the Executive Mansion, two triangular reservations on Pennsylvania avenue between Eighteenth and Nineteenth streets, triangular reservation on New York avenue between Tenth and Eleventh streets and Ashland Place, reservation on Massachusetts avenue between Fifth and Sixth streets.

It is the intention to make these maps, as well as others yet to be prepared, show the location of the various trees and shrubs, with the local and botanical name of each given, so that at any time in the future when a tree dies, an examination of the map would show what had been previously set, and thus enable the same species to be reset, so that the original plan of planting and arranging the trees can be maintained, and a comparison of the hardiness, length of life, &c., of the different varieties be kept.

Much difficulty has been experienced in locating water and sewer-drain pipes, which these maps will obviate.

I have to report that on the 22d day of October I received from Messrs. Latimer & Cleary, auctioneers, an account of sales of the old-wood buildings on Judiciary Square, sold by them August 12, 1873. The proceeds, $1,609.46, was paid to the managers of the Women's Christian Association, in accordance with the act of Congress authorizing their sale.

Permission was twice given during the year to menageries and circus companies to exhibit on the unimproved reservation between Four and a half and Sixth streets, upon condition that they should give $100 each time to some charitable institution in the city, and should admit the soldiers' and sailors' orphans free.

Of the $200 thus received, $150 was given to the Children's Hospital, a Christian institution, whose relief extends to all children, without distinction of color, and $50 to the Women's Christian Association, a very worthy charitable institution.

NAVY-YARD AND UPPER BRIDGES.

The Navy-yard and Benning's Bridges have received the necessary care and attention during the year, and travel has been uninterrupted. They have both received very extensive repairs, and are in as good condition as the appropriation for their care and preservation will permit.

The Navy-yard Bridge accommodates an immense travel, and requires almost constant repairing. On the 29th of July, 1873, as a four-horse team belonging to the Government Insane Asylum was crossing the Navy-yard Bridge, a span of the bridge broke, and let them through into the water. A patient from the hospital was seated with the driver, and narrowly escaped being drowned. Two of the horses were drowned. The bridge was immediately repaired. This bridge is the only direct means of communication with the asylum and Washington, and as it contains some six hundred and twenty-five patients, any interruption of this character is of serious embarrassment to the institution.

TELEGRAPH.

An appropriation was made by Congress for the purpose of connecting the Capitol with the Executive Departments and the Government Printing Office by a telegraph line, and directing the officer in charge of the public buildings and grounds to construct the line. Proposals were solicited from several parties engaged in that business, and it was awarded to the lowest bidder. The lines were erected, and proper instruments purchased and placed in position before the assembling of Congress in December. The lines were so arranged that the several Departments are connected with each other as well as with the Capitol.

To prevent disfiguring the Capitol Grounds, the wires were run from North Capitol street to the Capitol under ground. To accomplish this, two cables of five wires each were laid. At North Capitol street the various wires were attached to the cable, an ornamented iron post being used, through the center of which the wires were led. The line was kept in good working order during the session of Congress, and has proved of great service to the members and to the various Departments. The posts have received two coats of paint to preserve them and make their appearance in the city as unobjectionable as possible. A quantity of material was purchased, which will be available during

the coming year. I would respectfully recommend an extension of this line, so as to connect the navy-yard, arsenal, Smithsonian Institution, Department of Agriculture, the Naval Observatory, and other national institutions in the District of Columbia.

GOVERNMENT WATER-PIPES.

The Government water-pipes conducting water to the Capitol from Smith's Spring are laid along North Capitol street, in which street the board of public works has been constructing a large sewer. The nature of the work was such that the pipes were continually breaking. To correct this, and to avoid the necessity of digging up the street in case of a break, and to maintain the supply of water, the location of the line was changed, it being placed under the side or foot walks, just inside the curb. It was discovered in moving the pipe that many of the pieces had been destroyed by rust. These were replaced with new pipe. The supply of spring-water to the Capitol was not interrupted during the session of Congress.

EXECUTIVE MANSION.

The public and private portions of the Executive Mansion received the necessary care for the protection of the property and comfort of the President's family. The bath-tubs and water-closets were replaced with new ones. Great care was taken with the plumbing to prevent leaking. The floor of the bath-room was so arranged with lead that no water could get through and damage the ceilings below in case of an overflow or breakage of the pipes. The pipes leading from the basement were incased in zinc, to prevent rats and mice following along them and getting into the upper part of the house. One sleeping-room was repaired by being newly papered, a new grate put in, painted, and a new stationary marble wash-stand, to which hot and cold water pipes were attached. Hot and cold water pipes were led into other rooms. Two sleeping-rooms in the upper portion and one reception-room on the first floor of the house were papered. A large and roomy wardrobe, made of ash and walnut, was constructed, and placed in one of the rooms, it taking the place of an old and worthless one made of pine. Carpets of different styles have been purchased and put down in the several rooms as needed. New furniture was purchased and placed in the house when required. The carpets were taken up and thoroughly cleaned. The entire exterior of the Mansion was cleaned of cobwebs, &c., and places which suffered from the inclemency of the weather were covered with a light coat of paint to present a uniform color. The heating-apparatus and gas and water pipes have been repaired as necessity required.

GREEN-HOUSES.

An appropriation of $10,000 for continuing the permanent improvement of the green-houses was made by Congress. It was contemplated to use this in the construction of an iron superstructure to take the place of the present wooden one, which is old and decayed. Upon getting estimates it was found that the work would cost some $50,000, and therefore it was deemed advisable not to commence the work unless an additional appropriation was made. The house was kept in good repair, and so much of the appropriation as was necessary for that purpose was expended.

The unexpended balance was re-appropriated for care of and necessary repairs to the houses for the next fiscal year.

FUEL.

Advertisements soliciting bids for fuel for the Executive Mansion and the green-houses were published in the various papers of the city. The contract was awarded to Mr. C. T. Yoder, who has filled it in a satisfactory manner.

FINANCIAL STATEMENT.

The appropriations for the fiscal year just closed have all been expended, with the exception of that made for lighting the Capitol, Executive Mansion, and the public grounds, and for permanent repairs to the green-houses at the Executive Mansion, the unexpended balance for the former being $10,257.62, and the latter, $7,901.86. The unexpended balance of the lighting-fund will be covered into the Treasury. The unexpended balance for green-house was re-appropriated by the last Congress for the care of and necessary improvements to the same for the ensuing year.

The estimates submitted for the service of this office, for the fiscal year ending June 30, 1876, are as follows:

Salaries		$55,016 00
Contingent expenses of office		2,000 00
Repairs and refurnishing the Executive Mansion, care of green-house, and fuel for both		30,000 00
Lighting the Capitol, Executive Mansion, and the public grounds, purchase of lamps, lamp-posts, pay of lamp-lighters, and plumbing and gas-fitting of all sorts	$51,000 00	
For purchase of gas-fixtures for corridors of the House of Representatives, to correspond with those in the Senate	5,000 00	
		56,000 00
For repairs to the Navy-Yard and Upper bridges		7,000 00
For repairing and extending the Government water-pipes and those leading from Smith's Spring, that supplies the Capitol		10,000 00
For care and improvement of the public grounds, as follows, viz:		
For filling the grounds south of the Executive Mansion	10,000 00	
For subdraining, repairing, and regraveling the roads and walks of the Smithsonian grounds north of the building, and for construction of fountain	10,000 00	
For building approaches to the bridge to be erected over Sixth street by the Baltimore and Potomac Railroad Company	5,000 00	
For completing the improvement of the reservations between Third and Sixth streets, as per plan	10,000 00	
For improving various reservations along avenues, to harmonize with the work done by the board of public works	20,000 00	
For ordinary care of an extension to the green-houses at the Propagating Garden	5,000 00	
For ordinary care of Lafayette Square	2,000 00	
For the removal of the present cumbersome iron fence inclosing Lafayette Square, and substituting post and chain	5,000 00	
For paving 4,221 square yards of walks in Lafayette Square	10,552 50	
For annual repair of fences	2,000 00	
For manure and hauling the same	8,000 00	
For painting iron fences	4,000 00	
For purchase and repair of seats	1,000 00	
For hire of horses and carts	5,000 00	
For purchase and repair of tools	2,000 00	
For trees, tree-boxes, lime, and whitewashing	5,000 00	
For removing snow and ice	1,000 00	
For flowers, pots, twine, wire, italiens, lycopodeum, &c	1,000 00	
For purchase of trees and plants for nursery, and care of same	2,000 00	
For tree-markers and marking them	100 00	
For making cages and boxes for sparrows	500 00	
For abating nuisances	1,000 00	
For removing the ailantus trees from the public grounds, the same having been condemned by the board of health	500 00	
For care of and repairs to the various fountains	1,000 00	
For continuing the improvement of reservation No. 3, as per plan	20,000 00	
For excavating bottom and paving the side of the lake in the Monument grounds	5,000 00	

For replacing fountain on Fourteenth-street circle with marble		$2,500 00	
For improving Pacific Place circle, Massachusetts, Connecticut, and New Hampshire avenues		5,000 00	
For improving Stanton Place, at the intersection of Massachusetts and Maryland avenues		10,000 00	
For taking up and relaying curb and flag south of the Executive Mansion		1,500 00	
For cutting down embankment in the nursery		1,250 00	
For granite coping and fence in front of the Executive Mansion		7,450 00	
For repairing fountain south of the Executive Mansion, and for coping and center-piece for same		3,000 00	
For fountain and watchman's lodge in Judiciary Square		5,000 00	
For colossal statue of Lincoln, to be placed in Lincoln Square		20,000 00	
For pedestal for same		10,000 00	
For the purchase of triangular squares of ground west of square 624 and north of square 563, containing 17,564 feet	$17,564 00		
For improving the same	3,000 00		
		20,564 00	
For inclosing two triangular reservations on Ohio avenue, between Thirteenth and Fifteenth streets		3,000 00	
For the purchase of 300 seats for the public grounds		2,400 00	
For filling, grading, draining, and improving the reservation on Missouri avenue lately occupied by the Agricultural Department		10,000 00	
For removing the cast-iron fence from reservation on Pennsylvania avenue between Twentieth and Twenty-first streets, recasting it into park-posts, and for improving the same		1,500 00	
			$239,816 50
Grand total of estimates			397,832 50

To convey an idea of the labor required to make the improvements as detailed in the foregoing report, I would state that 29,375½ days' labor of men, 6,518 days' of horses and carts were expended, in addition to 962 months' of regular laborers.

In closing my report, I desire to express my appreciation of the valuable aid I have received in the prosecution of the work of this office from my assistant engineer, Mr. George D. Benjamin, whose ability has in no small degree contributed to its success. I wish, also, to mention most favorably Mr. George H. Gideon, in charge of bridges, and Mr. George H. Brown, the landscape gardener; Mr. Wm. H. Bailey, in charge of gas, water-pipes, &c., and Mr. James Balloch, in charge of accounts, for their hearty co-operation at all times and their earnest efforts for the successful administration of the office.

WASHINGTON AQUEDUCT.

On the 3d of March, 1873, the following appropriation was made by Congress, viz:

For wooden fence at the distributing-reservoir	$1,500
For dwelling for gate-keeper at distributing-reservoir	2,500
For completing stone bridge	8,600
For macadamizing conduit-road	16,000
For engineering, maintenance, and general repairs	15,000

Plans, specifications, and forms of contract for the work embraced in the above appropriation were made in July, and advertisements were issued inviting proposals for the same. Bids were received and opened on the 26th of August, and the several works were awarded to the lowest bidders.

The following is an abstract of the bids received:

Bidders.	Dwelling at distributing-reservoir.	Wooden fence at distributing-reservoir, per linear foot.	Macadamizing, per square yard.	Grading, per cubic yard.
Wilson & Reeside	$2,582 00	$0 70	$0 94	$0 30
Thomas Harvey	2,700 00	1 37½	1 20	44
Emmart & Smith	2,900 00	0 92	1 15	40
John H. Howlett	3,298 00	1 20	.....	.....
Anderson & Sunney	3,450 00	1 00	1 75	30
Thomas P. Morgan	.....	.....	0 80	30
Holmead & Eslin	.....	.....	1 00	38
Andrew Gleason	.....	.....	1 00	37
H. A. Garrett & Co	.....	.....	1 27	31
George B. Abrams	.....	1 25	1 50	42
E. P. Dougherty	.....	.....	1 45	35
N. C. Belt	.....	.....	1 45	52
Croply & Brewer	.....	.....	2 00	47

DISTRIBUTING-RESERVOIR.

The contract for the dwelling and wooden fence was awarded to Reeside & Wilson, of Washington, D. C., who commenced work on each structure in September.

The fence around the reservoir was completed in November; the dwelling was completed in December. The fence is composed of cedar posts placed 6 feet apart, from center to center, on which are spiked three rails, each 3 by 4 inches, in lengths of 18 feet. On the rails are nailed pickets, 1 by 4 inches, 6 feet long. The bottom board is 1 by 15 inches, in lengths of 18 feet. The total length of fence built is 1,524 feet, making, in addition to that previously built, 5,854 feet, which completes the fencing of this reservoir.

The dwelling consists of a superstructure of bricks, on stone foundations, surmounted by a slated Mansard roof, and contains six rooms, three in each story.

The grounds around the dwelling were graded and drained, and inclosed with a wooden picket-fence 5 feet in height.

The old buildings were taken down and the lumber used in the construction of a stable and store-house for tools. All the fences and outbuildings were thoroughly lime-washed.

The embankments at the auxiliary gate-house and the stone well-house were graded to a uniform slope and sodded.

The light-shaft of the pipe-vault in front of the effluent-gate house was finished with a cast-iron ventilator.

A stone culvert, 100 feet in length, with a water-way 3 feet square, was built across the road in front of "Drovers' Rest," and a ditch was excavated along the northerly boundary of the reservoir lands to intercept the surface-drainage of the drove-yard, and connected with the culvert, thus preventing the possibility of the surface-water from the cattle-yard reaching the distributing-reservoir.

Stone culverts were also built for the several water-courses crossing the pipe-line between the reservoir and Foundry Branch. Before building the culverts bids were received from responsible contractors, and the work was awarded to the lowest bidder, J. V. W. Vandenburg, of Washington.

MACADAMIZING AND GRADING.

The contract for macadamizing and grading was awarded to Thomas P. Morgan, of Washington, who commenced his work in September and completed it last July. The total length of road macadamized is 6,000 feet, amounting to 8,000 square yards.

The macadam laid by Mr. Morgan commences at the west end of tunnel F and continues to culvert No. 9.

The material used is principally gneiss rock, broken, with a steam crusher, so as to pass in any direction through a 2½-inch ring. The width of macadam is 12 feet, the depth 1 foot, placed on the roadway in layers of 4 inches, and each layer thoroughly rolled with a heavy stone cylinder. The roadway was previously prepared by widening the excavations and embankments. The embankments were also widened over culverts Nos. 25 and 26 and at each end of Cabin John Bridge.

A roadway was graded and prepared for macadam along the northerly front of the distributing-reservoir and over the pipe line for a distance of 5,000 feet.

The total quantities of work done by Mr. Morgan are as follows:

Macadam	8,000 square yards.
Excavation	22,560 cubic yards.
Paved ditches	181 square yards.

STONE BRIDGES.

The contract for completing the coping and parapets of stone bridges was awarded to Thomas Harvey, of Washington. He commenced work in September, and completed the coping and parapets of bridge No. 3 in December. The plan adopted is similar to that for Cabin John Bridge. The stone was quarried from the Government quarries at Seneca. The length of the parapets is 200 feet each, and they contain 2,945 cubic feet of cut stone.

For bridges Nos. 1 and 2 the coping was made of concrete. There being no roadway over these bridges, parapets are not required. The concrete was composed of broken stone, sand, and hydraulic cement, mixed in the following proportions:

1 barrel of Round-Top cement.
10 cubic feet of river sand.
18 cubic feet of broken stone.

The stone was broken small so as to pass in any direction through a 2-inch ring.

The cement and sand were mixed dry, in a large box; sufficient water was added to make mortar; after which the broken stone was thrown in and the whole mass turned over twice with shovels and hoes and used immediately.

It was deposited in layers of 4 inches in depth, and each layer was rammed with a wooden rammer until the mortar flushed to the surface. The third and last layer was worked perfectly smooth on top, and the surface was divided into rectangles, 4 feet wide by 9 feet long, with wooden moulds, which, being removed after the concrete had set, formed suitable grooves for the surface-drainage. Previous to laying the concrete, a belt-course of cut stone, 1 foot wide, 1 foot thick, and in lengths of 9 feet, was laid entirely around the deck of each bridge.

POTOMAC DAM.

The cut-stone dam over the Maryland channel of the Potomac River recently was examined, and found to be in good condition. In July ad-

vantage was taken of the low stage of the water in the river to replace a part of the riprap protection above the dam, and which had been carried over the dam by the spring freshets. To a certain extent similar work has to be done once a year, and comprises the only repairs made on this structure since its completion in 1867. The feeder under the Chesapeake and Ohio Canal was cleaned out from end to end.

PIPE-LINE.

The pipe-line is in good condition, and during the year no leaks of any importance have occurred. All of the stop-cocks have been kept clean and in working order, and the vaults have been lime-washed. Stone pavements were laid around the vaults on the canal-road.

IRON BRIDGES.

Bridge No. 5, over College Pond, is in good order. The floor of bridge No. 6, over Rock Creek, has been kept in repair. The following, in reference to this structure, is extracted from my last annual report:

> There seems to be no authority of law for the use of this bridge for common travel. The constant jarring to which it is subjected has caused many of the ornamental scrolls which encircle the joints of the mains to become loose and drop, and I have no doubt its continued use for a general thoroughfare will eventually destroy its usefulness for aqueduct purposes.

WATER-PRESSURE ENGINE.

The Worthington water-pressure engine that supplies a part of Georgetown heights with Potomac water has been kept in almost constant operation. It has been stopped only for short intervals to replace the rubber springs as they wore out, and for other slight repairs. The valves and pistons have become much worn, and will soon have to be renewed. The cylinders are also worn, and should be rebored.

The acqueduct lands at Rock Creek bridge have been graded and sodded, and enclosed with a substantial fence. In the work-shop at this point a "band-saw" and grindstones have been set, also a 10-inch turbine to work them.

HIGH-SERVICE RESERVOIR.

The grounds at this reservoir have been kept in good order. The gallery under the reservoir and the wooden fences around the grounds have been lime-washed.

CONSUMPTION OF WATER.

The quantity of water supplied during the year has averaged over 17,000,000 gallons daily. The surface of water at the distributing-reservoir has been kept at the elevation of + 144 feet above tide-water. To maintain this elevation the conduit from culvert No. 19 to the distributing reservoir has been run under a head. Since the embankments over this portion of the aqueduct were widened and raised there have been no leaks in the conduit. Before the embankments were increased the conduit leaked whenever the water in the distributing-reservoir was raised above + 142.

The water-supply has been very clear, except during a part of the month of April, when it was riley for a few days, owing to the long-continued turbid condition of the Potomac.

During the summer months the surface of water in the Potomac falls considerably below the crest of the Potomac Dam, and it has been difficult to keep the surface in the reservoirs up to + 144.

In July and August of the present year this elevation has not been

constantly maintained, the surface being often as low as + 143, showing that the daily consumption is more than the minimum flow of the Maryland channel of the Potomac.

WORK YET TO BE DONE.

At Great Falls the Potomac Dam should be built entirely across the river of the Virginia shore, and the gate-house should be finished with a slated roof, supported by a wrought-iron frame. The walls should be finished with galvanized-iron cornice.

The receiving-reservoir will always be used for the storage of water, to be kept for use in case of accidents happening to the conduit above, or when the Potomac is swollen and unfit for use. It should be inclosed by a substantial wooden fence.

The remainder of the roadway over the conduit should be finished and the embankment widened. The slopes should be soiled and seeded, in order to prevent washing by the rains.

At the receiving-reservoir a dwelling should be built for the gate-keeper, similar to that built at the distributing-reservoir.

The outer slopes of the distributing-reservoir should be soiled and seeded in order to prevent washing by the rains.

The estimates for which appropriations should be made for the next fiscal year are as follows:

For engineering, maintaining, and general repairs	$15,000 00
For building an iron truss-roof and furnishing and setting galvanized-iron cornice on the gate-house at Great Falls	3,000 00
For building a stone dam across the Virginia channel of the Potomac River	200,000 00
For building dwelling for gate-keeper at receiving-reservoir	3,000 00
For building a wooden fence around the receiving-reservoir	9,528 00
For continuing macadamizing and widening of conduit-road	10,000 00
For soiling and seeding embankment-slopes of distributing-reservoir	13,000 00
For soiling and seeding the slopes of the conduit-embankments from Great Falls to distributing-reservoir	27,050 00
	280,578 00

The following is a financial statement for the last fiscal year, ending June 30, 1874:

Titles of appropriations.	Available July 1, 1873.	Expended in 1873-'74.	Available July 1, 1874.
Act of July 15, 1870.			
Slope-wall of distributing-reservoir	$1,086 59	$1,086 59	.....
Repairs of Tunnel No. 1, and removing fallen stones	01	01	.....
Cleaning out obstructions above dam heading aqueduct	01	01	.....
Preserving new or Delecarlia Tunnel	176 65	176 65	.....
Act of March 3, 1871.			
Earthwork and slope-wall of Division Dam	2,024 02	2,024 02	.....
Act of June 10, 1872.			
Completing parapets of Cabin John and other bridges	6,805 72	6,805 72	.....
Dial-telegraph from Great Falls to Washington	2,429 00	2,429 00	.....
Excavation of distributing-reservoir	3,736 71	3,736 71	.....
Act of March 3, 1873.			
Engineering, maintenance, and repairing	15,000 00	15,000 00	.....
Macadamizing conduit-road	16,000 00	14,965 65	1,034 35
Completing stone bridges	8,600 00	8,600 00	.....
Dwelling for gate-keeper	2,500 00	2,500 00	.....
Wooden fence at distributing reservoir	1,500 00	1,500 00	.....

The above balance of the act of March 3, 1873, was expended last month.

Col. T. B. Samo, who has been the assistant engineer in charge of the aqueduct office for the last ten years, has rendered most efficient assistance in its care and the prosecution of the work during the year, and Mr. R. Dunning, in charge of the office, has given it most faithful attention and service.

Very respectfully, your obedient servant,

O. E. BABCOCK,
Colonel of Engineers, U. S. A.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

APPENDIX CC.

ANNUAL REPORT OF MAJOR C. B. COMSTOCK, CORPS OF ENGINEERS, FOR THE FISCAL YEAR ENDING JUNE 30, 1874.

SURVEY OF THE NORTHERN AND NORTHWESTERN LAKES.

U. S. LAKE SURVEY OFFICE,
Detroit, Mich., August 1, 1874.

GENERAL: I have the honor to submit the annual report of the survey of the northern and northwestern lakes for the fiscal year ending June 30, 1874.

LAKE SUPERIOR.

The work of connecting the triangulation of Lake Superior with that of Lake Michigan, which had already been begun, was continued under great difficulties, by Assistant Engineers Wisner and Marr, during the fall of 1873 and the early summer of 1874. Aside from the difficulty in getting weather good enough to read angles in, the country in which stations were to be erected was a dense forest, without any traveled roads, and, especially in the spring of 1874, rendered almost impassable by long-continued rains. These difficulties, and the results accomplished, are stated in the reports of Assistant Engineers Wisner and Marr, given in Appendix A. At the date of this report all the angles have been read, and the connection is completed. Assistant Engineer Wisner, in addition to reading horizontal angles, determined the latitude of the south end of Keweenaw base-line and the azimuth of the base. The Keweenaw base was re-measured during the fall of 1873 by Assistant Engineer E. S. Wheeler, whose report will be found in Appendix A.

LAKE MICHIGAN.

At the beginning of the fiscal year, Assistant Engineers Flint and Woodward were engaged in reading the angles of the primary triangulation along the western shore of Lake Michigan. During the fall, the angles of this triangulation were read from Waterford to Deerfield, in the vicinity of Chicago. They also reread, later in the fall and in the spring of 1874, some of the triangles in Green Bay, so that now there is a continuous chain of well-read triangles reaching from St. Ignace, on the north shore of Lake Superior, to the immediate vicinity of Chicago,

and furnishing an arc of the meridian four hundred and fifty miles long.

Assistant Engineer Flint also made a careful determination of latitude and azimuth at Minnesota Junction.

Details of the work accomplished by Assistant Engineers Flint and Woodward will be found in Appendix A.

There remained at the close of the last fiscal year a portion of off-shore hydrography and of topography at the southern end of Lake Michigan still uncompleted. Lieut. D. W. Lockwood, with the steamer Search, continued and completed the off-shore hydrography and built needed stations in Green Bay, and Assistant Engineer Custer completed the topography. The latter, late in the fall, was sent to the St. Lawrence River. The amount of work performed by Lieutenant Lockwood and by Assistant Engineer Custer is given in detail in their reports in Appendix A.

A line of azimuths and latitudes on the west shore of Lake Michigan had been begun by Lieutenant Powell, and was completed by him in the fall of 1873. It begins at station Portage, whose latitude and longitude are determined by geodetic connection with Fort Howard, and extends to Milwaukee, giving the latitudes and longitudes of numerous points along the west shore of Lake Michigan, thus checking the topographical work.

On the east shore of Lake Michigan, the line of azimuths and latitudes starts from station Point aux Becs Scies, geodetically connected with Fort Howard, and was continued by Lieutenant Maguire to South Haven, near which point it will connect with the triangulation at the south end of the lake.

The work needed to complete the Wisconsin triangulation is only the reading of the angles of the triangles at the south end of the lake. Ultimately, a base should be measured south of Chicago to verify the triangulation north of that city, and to continue the triangulation east to Lake Erie and south into Illinois. The reports of Lieutenants Maguire and Powell will be found in Appendix A.

DETROIT RIVER.

The serious losses to commerce occurring by vessels grounding where the Detroit River enters Lake Erie, and at a place called the Lime Kilns, on the Detroit River, having shown that the old charts of those places were not in sufficient detail, a resurvey of the river was undertaken, and completed in the fall of 1873, and a preliminary chart published in the spring of 1874. The losses last year from lack of such a chart probably amounted to $50,000 or $75,000. The survey was made by Assistant Engineer Lamson, whose report will be found in Appendix A.

ST. LAWRENCE RIVER.

During the year, the topography and hydrography of this river have been completed, extending from the head of Welles Island to Lake Ontario, while the triangulation has been made continuous from the forty-fifth parallel to Clayton, and then extended to Lake Ontario. The triangulation has been made by Lieutenant Bailey, and Assistant Engineers Foote, Metcalf, Russell, and Darling; the topography by Assistant Engineers Towar, Custer, Mayer, Eisenmann, and Terry; the hydrography by the same parties, and by Captain Livermore.

Reports of Assistant Engineers Mayer and Towar will be found in Appendix A.

LAKE ONTARIO.

A reconnoissance for triangulation has been carried by Capt. W. R. Livermore and Assistant Engineer E. S. Wheeler from Cape Vincent west to Big Sodus, and a base has been selected on the beach near Sandy Creek. Several of the stations have been erected. The topography and in-shore hydrography are in progress on the south shore from Cape Vincent to Galop Island, the parties being those of Assistant Engineers Mayer and Eisenmann, while on the north shore the parties of Assistant Engineers Towar and Terry are carrying the topography and in-shore hydrography along Wolf and Amherst Islands.

Lieut. D. W. Lockwood, on the steamer Ada, is charged with moving and supplying parties, reconnoissance for stations and their erection, and off-shore hydrography.

LONGITUDE-WORK.

At the request of the geological survey of Wisconsin, the determination of the latitudes and longitudes of points on some of the correction-lines and principal meridians of the land-surveys in Wisconsin was undertaken in 1873. A number of points have been determined, but the reductions have been made only for points near Galena, Ill., Valley Junction, Wis., and Stillwater, Minn. Assistant Engineer O. B. Wheeler was assigned to the longitude-work at Detroit; and as no officer or assistant could be spared for the field, the services of Prof. S. W. Robinson, who had previously served on the lake survey, were obtained. All the work was reduced in the office during the winter, and the results are reported by Assistant Engineer O. B. Wheeler in Appendix B.

At the request of Lieut. G. M. Wheeler, the lake-survey co-operated in 1873 with Dr. Kampf in the determination of the longitude of Ogden, Utah. Assistant Engineer O. B. Wheeler was the observer at Detroit. The work has been reduced, and the results are reported in Appendix C.

At the request of the governor of Michigan, the determination of the positions of some principal points in the interior of the State has been undertaken.

Lieut. E. Maguire was assigned, in the spring of 1874, as observer at Detroit, and Lieut. C. F. Powell as field-observer. The weather during May and June was exceedingly unfavorable, but Lapeer, Flint, and Pontiac have been occupied for both latitude and longitude by Lieutenant Powell.

MAGNETIC WORK.

Capt. A. N. Lee continued his magnetic work during July and August, 1873, visiting several stations in the vicinity of the great lakes. His report is given in Appendix D.

The following is a general summary of the field-work during the year:

Longitudes determined telegraphically	6
Latitudes determined	12
Primary azimuths	7
Primary-triangulation stations occupied	37
Primary base-line measured	1
Miles of developed shore-line surveyed	544
Square miles of topography	193
Square miles of in-shore hydrography	214
Square miles of off-shore hydrography	1,210

OFFICE-WORK.

During the winter, the length of the Keweenaw base was computed by Assistant Engineers E. S. Wheeler and R. S. Woodward. Its computed length is subject to a slight correction, depending on the value finally adopted for the length of the standard 15-foot bar at a temperature of 32° Fahrenheit.

An attempt has been made to estimate the probable error in the measurement alone, omitting all consideration of error in the assumed length of the standard. While the determination of the probable errors in measurement with an instrument whose length is made up of so many parts, all liable to small changes, and of so complicated construction, necessarily requires many assumptions, yet the discussion seems to show that it is capable of tolerably good work, without, however, reaching the precision attained with the base-apparatus of Repsold or Brunner. The results are given in Appendix E.

There being some uncertainty as to the accuracy of the screw of the Würdemann comparator, Lieutenant Lockwood was directed to examine it. His report will be found in Appendix F.

A new series of tests of the thermometers in use being deemed necessary, the work was intrusted to Assistant Engineer Russell. His results will be found in Appendix G.

A series of comparisons of the new lake-survey yards 6, 7, 8, 9, 10, with each other, was made under my direction, (in a room whose temperature was made as steady as possible,) by Assistant Engineer E. S. Wheeler, and the results are reported in Appendix H.

It is also deemed best to report a series of comparisons of these yards with the 15-foot standard bar, although during some of them the stability of temperature was much less than in the preceding. These are given in Appendix I.

The constants of the 14-inch non-repeating Simms theodolite having been partially determined, Assistant Engineer Wisner was directed to complete their determination. His results are given in Appendix J.

The field-work generally has been reduced, and the work of the topographical and hydrographical parties has been platted on 23 sheets of antiquarian paper. Meteorological observations have been continued during the year at Port Austin, Monroe, Mich., and at Sackett's Harbor, N. Y. The results are given in Appendix K.

The results of the water-level observations for the year are given graphically on Plate I.

During the year, Mr. Mueller has completed for the engraver a final chart of Sandusky Harbor on a scale of $\frac{1}{2000}$, and has corrected the charts of "North end of Lake Michigan," "Straits of Mackinac," and "Beaver Group," so as to include hydrography finished since their completion. He has made progress on the final chart of "South end of Lake Michigan" on a scale of $\frac{1}{40000}$.

Mr. Molitor has completed on stone a preliminary chart of the mouth of Detroit River on a scale of $\frac{1}{3000}$, and the chart has been printed. It was much needed. He has also completed, except the lettering, a final chart of Lake St. Clair; scale, $\frac{1}{5000}$.

Mr. Witzleben has completed a map of Chicago; scale, $\frac{1}{2000}$.

Chart No. 1, of the St. Lawrence River, is nearly completed; scale, $\frac{1}{30000}$.

Mr. Fisher has made progress on chart No. 2 of the St. Lawrence River; scale, $\frac{1}{30000}$.

There are forwarded herewith a sketch showing the general progress

of the lake-survey and a sketch showing the triangulation in Wisconsin.

The following changes of officers under my command took place during the year:

Capt. W. R. Livermore, relieved May 26.
Capt. A. N. Lee, relieved February 28.
First Lieut. H. M. Adams, joined June 8.
Second Lieut. T. M. Bailey, joined June 1.

To the officers and assistants of the lake-survey my thanks are due for their hearty assistance in the work.

The need that the survey of the lakes should be vigorously prosecuted is best shown by the number of charts required by the commerce of the lakes, now five or six thousand a year, and by the constant inquiry and pressure for charts not yet completed, or for which not even the surveys have, as yet, been made.

It is judged that the single survey made last year of the mouth of Detroit River and of a part of Lake Erie will save from $50,000 to $100,000 to commerce this year.

Financial statement.

Amount expended during fiscal year 1873–'74	$175,000
Amount available for fiscal year 1874–'75	175,000
Amount required for survey of northern and northwestern lakes for fiscal year ending June 30, 1876: For continuation of surveys of Lakes Ontario and Erie; determination of points in Michigan, in aid of State survey; extension of triangulation south from Chicago; and miscellaneous	219,000

Estimate of funds for continuance of the survey of the northern and northwestern lakes for the fiscal year ending June 30, 1876.

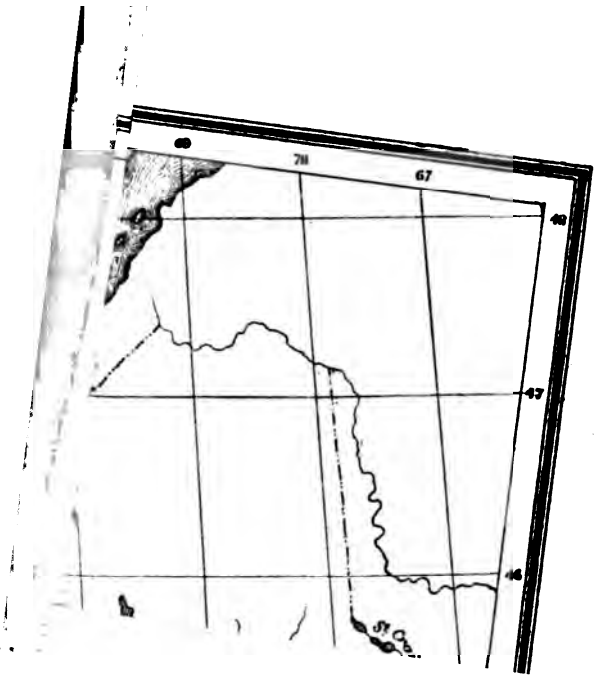
For continuing surveys of Lakes Ontario and Erie; determination of points in Michigan, in aid of State survey; extension of triangulation south from Chicago; and miscellaneous, $219,000. Details as follows:

Continuance of survey of Lake Ontario, and reduction of the work:	
Triangulation, six parties	$30,000
Topography, four parties	52,000
Hydrography, two steamer-parties	30,000
Survey of Lake Erie, and reduction of the work:	
Triangulation, four parties	20,000
Topography, two parties	26,000
Hydrography, one steamer-party	15,000
Survey of Lake Michigan:	
Reduction of previous work; determination of points in interior of Michigan, in aid of State survey; and extension of triangulation south from Chicago	25,000
Miscellaneous:	
Water-level and meteorological observations and reductions, $5,000; transportation of parties, quarters, and fuel for officers, $6,000; office-rent, fuel, stationery, and instruments, $5,000; completion of unfinished work, $5,000	21,000
Total	219,000

Very respectfully, your obedient servant,

C. B. COMSTOCK,
Major of Engineers and Bvt. Brig. Gen.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.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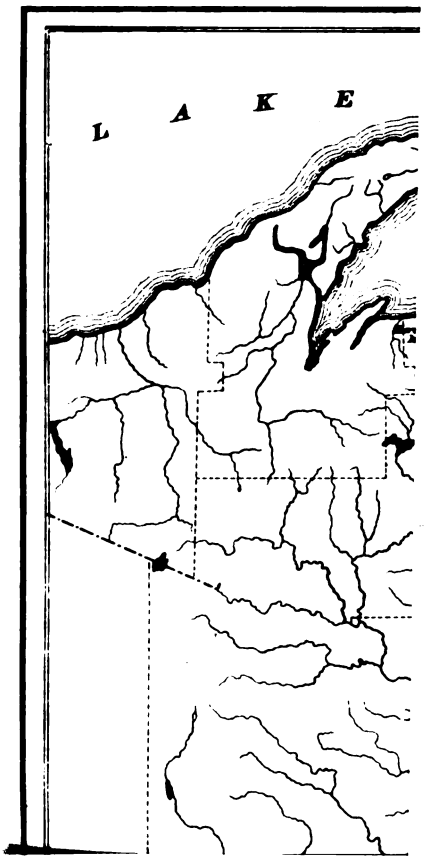
L A K E

APPENDIX A.—FIELD-WORK.

1.—*Report of Mr. George Y. Wisner, Assistant Engineer.*

FAYETTE, MICH., *June* 30, 1874.

GENERAL: I have the honor to submit the following report upon the operations of the parties assigned to my charge during the past fiscal year.

During the season of 1873, the parties under my immediate direction were that of the steamer Surveyor, a triangulation-party, and a station-building party, with orders to work in connection with Assistant Engineer G. A. Marr, in carrying a system of triangulation from Lake Superior to Green Bay.

During the month of June, 1873, the parties had been distributed at their respective stations, and with the beginning of the fiscal year I commenced measuring angles at station Triloba.

After having occupied stations Triloba and Shelter Bay, I proceeded with steamer to south base Keweenaw Bay, and made a series of observations for the latitude of that station and azimuth Keweenaw base line. By the time this work was completed, the station-party had finished building the large stations at Divide and Mud Lake, and as Aassistant Engineer Wright, who had been assigned to assist me in locating stations, had been recalled to the office, I was obliged to discontinue instrumental work, and go with steamer and station-party to Green Bay to definitely locate the stations, at Sturgeon, Monistique, and Fishdam.

The character of the country crossed by this system of triangulation rendered reconnoitering and station-building extremely difficult.

The land was heavily wooded and interspersed with almost impassable swamp, and in some instances, in order to obtain the required height for the larger stations, we were obliged to raise a pole from thirty to forty feet above the general level of the forest, and reconnoiter by climbing the pole till the necessary height was reached for seeing the other station. Owing to a severe strain received while doing this work, I was detained at Green Bay much beyond the time expected, and, on returning to Lake Superior the fore part of September, every effort was made to complete the work on that side before the close of the season; but the severe storms that then set in rendered it impossible to do instrumental work, and on October 13th, the weather becoming so inclement that there was no hope of our being able to do anything more, the parties broke camp and returned to Detroit.

After returning to office, I was engaged till close of year in determining the instrumental constants of instrument used during the season, and in computing the season's field-notes.

From the beginning of the present year until leaving the office again for field-work, I was occupied in computing the observations for azimuth made by Assistant Engineer A. R. Flint in 1872 and 1873; Lieutenant Powell's observations for latitude, made during 1872 and 1873; and Lieutenant Maguire's observations for latitude and azimuth of 1873.

On May 5 I left Detroit with a triangulation-party, on board the steamer Search, for Green Bay, to work in connection with Assistant Engineer Marr, on Lake Superior, in making the necessary measurements for completing the work commenced last season. On May 10 the steamer landed my party at the mouth of the Sturgeon River, and the work of transferring instruments and necessary camp-equipage to the Monistique station was at once commenced. But, owing to the high stage of water in the rivers and swamps, we were ten days in reaching that station.

Being entirely cut off from all communication with the parties on the bay, we had to depend on our own resources, and in one case had to send a distance of fifty miles in order to reach and re-adjust a signal we were unable to read to.

On May 30 work at the Monistique station was completed, and, as soon as the instruments could be transferred, operations were commenced at Sturgeon. Here, however, it was found that the party in charge of building of stations on Green Bay the previous fall had made a mistake in regard to being able to see Sturgeon from Ford River, and, consequently, I was detained until Assistant Engineer Flint could locate and build a station at Pine Hill, near the head of Little Bay des Noquet.

On June 17 the work at Sturgeon station was finished, and on the 20th I again reached the mouth of Sturgeon River with party, having been forty days in the woods and swamps between the Sturgeon and Monistique Rivers, during which time the weather averaged rainy at least two days in three, thus keeping everything wet the most of the time, and often completely spoiling our provisions in packing through from supply-camp to station, a distance of twenty miles.

On June 22 the steamer assisted me in moving to Fishdam station, the work at which place was finished on the 24th, thus completing the connection of the Lake Superior triangulation with that of Green Bay.

The general health of party has been good throughout, considering the exposure and hardships to which all were subjected, and I am under many obligations for the hearty co-operation of all and the cheerful performance of all duties required.

The following is a summary of work accomplished during the year:

1873.

Number of stations built	6
Number of triangulation-stations occupied	3
Number of latitude-stations occupied	1
Number of azimuth-stations occupied	1
Number of primary angles measured	12
Number of secondary angles measured	10

1874.

Number of triangulation-stations occupied	3
Number of angles measured	13

Office-work.

Computation of observations for latitude made at 10 stations. Computation of observations for azimuth made at 5 stations. Computation of field-notes of triangulation at 3 stations. Computation for value of micrometer of Z. T. No. 1, made at 2 stations. Determination of instrumental constants of T. & S. 14-inch theodolite.

Very respectfully submitted.

GEO. Y. WISNER,
Assistant Engineer.

Gen. C. B. COMSTOCK,
Superintendent United States Lake-Survey.

2.—*Report of Mr. G. A. Marr, Assistant Engineer.*

CAMP SHELTER BAY, LAKE SUPERIOR, *July* 1, 1874.

GENERAL: I have the honor to make the following report for the fiscal year ending June 30, 1874:

At the beginning of the year, was stationed on Granite Island, Lake Superior, for duty on main triangulation.

Was detained at this station nearly two weeks after the main part of the work was done, on account of not being able to see the flash at Vulcan station. Finally, on August 5, Assistant Engineer Wisner visited that station, and succeeded in giving a flash.

Was transferred to Marquette August 6, where we went into camp at the mouth of Carp River for observations at station Mesnard.

While at this camp, besides observing the angles of the main triangulation, made a secondary triangulation, in order to locate churches, public buildings, &c., in Marquette; also, did some leveling in connection with the water-gauge at that place.

Left Marquette for Grand Island August 27, landing that night. Went into camp for work at the main station on Grand Island.

As one of the lines of sight from this station had not been cut in the right direction, several days were spent in watching the hill, which showed in this supposed cut to Mud Lake station, but finally concluded it must be out of place.

It was not until September 20 that the line was cleared in the right direction, and as the unfavorable weather of autumn had set in, the remaining work at this station was obtained under quite unfavorable circumstances.

Left Grand Island for Detroit October 9, and reported at the office in Detroit October 13. On October 20 received instructions to select some station near Detroit, in the triangulation of Detroit River, for observing azimuth, and also to observe the angles at several stations from Detroit up to Lake St. Clair. A large post was put up on Belle Isle for observing azimuth, but on account of snow-storms and very unfavorable weather, the azimuth-work was not finished until November 5. As there were but very few days during the winter fit for measuring angles, the triangulation of Detroit River was not fully connected with that of Lake St. Clair till just before leaving the office for field-work in May, 1874.

Was at work in the office during the winter, except on such days as were fit for field-work. The results for angles in the Lake Superior work were tabulated, and the mean results, corrections for signals, the probable errors, &c., all worked up. A computation of a part of the triangulation of Detroit River and a recomputation of the base near Wyandotte were made, and a geodetic computation of the whole triangulation of Detroit River.

At two of the stations in the triangulation of the river, the instrument could not be set up in center of station, and small bases were measured and the proper corrections made for reduction to center.

The computations for azimuth at Belle Isle were also made. April 17, received instructions to connect triangulation-station Milk River Point, on Lake St. Clair, with east end of land-survey base-line of Michigan. This work was completed April 22.

Left Detroit May 9 for field-work on Lake Superior, having a party of one recorder and seven men.

The summation of work in the field is as follows:

LAKE SUPERIOR—SUMMER OF 1873.

Main triangulation.

Theodolite-pointings	1,145
Theodolite-readings	2,380
Results for angles	698

Secondary work.

Theodolite-pointings	247
Theodolite-readings	302

Triangulation, Detroit River.

Theodolite-pointings	1,799
Theodolite-readings	1,580
Results for angles	325

Azimuth-work.

Theodolite-pointings	300
Theodolite-readings	900
Results for azimuth	136
Stars for time	13
Small bases chained, (total in meters)	1,096

LAKE SUPERIOR—SEASON OF 1874.

Main triangulation.

Theodolite-pointings	609
Theodolite-readings	1,164
Results for angles	361

Secondary work.

Theodolite-pointings	106
Theodolite-readings	184
Chaining, (in meters)	408.4
Vertical angles measured	3

During the season of 1873 I had as recorder Mr. C. W. Clark, who proved himself a very practical and reliable man, and has my sincere thanks for his cheerful co-operation at all times.

At present I have Mr. George C. Comstock as recorder, who has shown much ability for the work, and will undoubtedly render valuable service to the survey.

Very respectfully, your obedient servant,

G. A. MARR,
Assistant Engineer.

Gen. C. B. COMSTOCK,
Major Corps of Engineers, U. S. A.

3.—*Report of Mr. E. S. Wheeler, Assistant Engineer.*

OFFICE UNITED STATES LAKE SURVEY,
Detroit, July 1, 1874.

SIR: I have the honor to report the following field and office work during the last year:

July 1, 1873, I was ordered to remeasure the Keweenaw base-line. Assistant Engineers Burton and Pratt and Recorder Goldsmith were detailed to assist me.

My party consisted of eighteen men, with the usual outfit. The instruments were the primary base-apparatus; Blunt theodolite No. 1; and a Würdemann level and rod.

The party, with instruments and camp-equipage, left Detroit July 3, and landed at the base-line July 8. Comparisons of the tubes with the standard bar commenced July 16, and were continued till August 12. The measurement of the south part of the line was completed September 6, and the whole line September 25. The remeasurements were completed October 9, after which comparisons were made until October 15.

The whole number of tubes in the line is 1,933. The first 94 tubes were measured seven times. Therefore the whole number of tubes measured was 2,497.

Measuring was done on 32 days, making an average of 78 tubes per day. The party was in the field 87 working days, 40 of which were spent in comparing, 32 in measuring, 7 in making camp, setting comparator-posts, and general preparations, 2 in waiting for steamer after work was done, and 6 were stormy.

Camp was broken up on the 17th of October. Mr. Burton brought the party to Detroit, arriving here on the 21st of October.

My thanks are due Messrs. Burton and Pratt for the energy and care with which they executed all work intrusted to them. After my party started to Detroit I was ordered to the south end of Lake Michigan, to inspect the stations at Deerfield, Palatine, Park Ridge, Danby, Willow Springs, Miller's, Michigan City, Otis, and Springville, which I did, and arrived in Detroit November 1.

I was then ordered to arrange one end of the cellar under the lake-survey office for a comparator-room, setting the new comparator-posts on brick piers, ceiling the sides and top of the room, and packing them with sawdust, and making a double door.

A series of 60 comparisons between the five new yards and the standard bar was made, lasting from December 8 to December 30. The standard yards were then compared with each other from January 14, 1874, until March 9. These comparisons have been discussed, and results given in report No. 254.

The computation of the Keweenaw base-line was completed May 1. May 5 I was ordered to examine the water-gauges at Cleveland, Erie, Charlotte, and Sackett's Harbor, to select a suitable primary base-line near the east end of Lake Ontario, and to continue the reconnoissance for triangulation along the south shore of Lake Ontario westward. I completed the examination of water-gauges May 14. A base-line was selected on the shore of the east end of Lake Ontario, between the mouths of Big and Little Sandy Creeks. Four stations are necessary to connect this base with the primary triangulation; two at the extremities of the line, one near the village of Sandy Creek, and another near the village of Mannsville. All these points were selected and marked. The reconnoissance for triangulation was continued as far westward as Big Sodus.

The points selected for stations: Grand Point and Prince Edward's Island, Canada, Big Sodus, hill in Victory Township, hill in Butler Township, and a hill in Lyons Township.

All of these points, except the first named, were visited and marked. June 12 I was ordered to return to Detroit and make a second series of comparisons of the standard yards at a temperature as near 62° as possible. The comparisons were begun June 18, and have been continued until the present time.

Very respectfully, your obedient servant,

E. S. WHEELER,
Assistant Engineer.

Gen. C. B. COMSTOCK.

4.—*Report of Mr. A. R. Flint, Assistant Engineer.*

UNITED STATES STEAMER SEARCH,
Hedge-Hog Harbor, July 3, 1874.

GENERAL: I have the honor to submit the following report upon field and office work done during the fiscal year ending June 30, 1874.

At the beginning of the year I was in charge of the primary triangulation on the west side of Lake Michigan, Assistant Engineer R. S. Woodward working in connection with me.

From July 1 to August 23 the triangulation had been completed from Caledonia and Waterford, Wis., as far southward as Deerfield and Palatine, Ill.

Churches or public buildings were located in Racine and Kenosha, Wis., and in Waukegan, Highland Park, and Evanston, Ill.

From the 28th of August to the 10th of September I was making observations for a thorough determination of latitude and azimuth at Minnesota Junction Station, Wis.

After finishing this work I was ordered to Green Bay, to carry the primary triangulation as far northward as possible from Fort Howard during the season.

Owing to stormy and very unfavorable weather, the work was only completed as far as Peshtigo, Wis., by the middle of October; and as the season was so far advanced, the triangulation in Green Bay was discontinued, and an attempt made to carry the primary triangulation in Illinois as far as Chicago.

The weather proved to be extremely unfavorable for reading angles, and, as no substantial progress had been made by the 4th of November, Assistant Engineer Woodward and myself returned to Detroit.

All the stations occupied during the year, and those occupied by myself in Wisconsin in 1872, were permanently marked; one stone being set about three feet below the surface of the ground to mark the trigonometrical point, and three reference-stones, each rising about six inches above the surface.

A section-corner on the correction-line near Appleton, Wis., was connected with the primary triangulation, and also the northwest corner of Benton Township, in Illinois; the latter point being on the State line between Wisconsin and Illinois.

During the winter-months I was engaged in reducing my observations for latitude and azimuth made at Minnesota Junction in 1873, and for azimuth made in 1872 at Bruce Station, Wis.

I was also engaged during February and March in reducing latitude and azimuth observations made by Lieuts. E. Maguire and C. F. Powell during the season of 1873.

At Point aux Becs Scies, Clay Banks, and South Haven, Mich., and Fox Point, Wis., I also observed and reduced observations for determining the value of one turn of the micrometer-screw of zenith-telescope No. 19.

Reports in detail have been submitted on all office-work.

On the 1st of May, 1874, I was assigned to the charge of the steamer Search to complete the primary triangulation of Green Bay, working in connection with Assistant Engineers G. Y. Wisner and R. S. Woodward.

It was hoped to complete the triangulation by the 30th of June, but stormy and foggy weather has prevented it.

Some delay was caused by my party having to locate and build a station to connect the Green Bay triangulation with that brought overland from Lake Superior.

Two weeks were spent in this work.

It was reported by the station-building party in 1873 that all the stations necessary for making the connection had been built, but it seems that no reconnoissance was made, or the error would have been discovered.

On the 30th of June five stations remained to be occupied before the triangulation of Green Bay would be completed.

During the year I have been efficiently aided by Recorders V. H. Laur and W. C. Ells, and I have especially to acknowledge the valuable assistance rendered by Assistant Engineer R. S. Woodward. His field-work is entitled to the highest credit.

The following is a statement of the field-work for the fiscal year:

Triangulation in 1873.

Number of stations occupied on the west shore of Lake Michigan	5
Number of primary angles measured	24
Number of secondary angles measured	8
Number of stations occupied in Green Bay	3
Number of primary angles measured	13
Number of secondary angles measured	3

Latitude.

Number of nights observed	4
Number of pairs of stars observed	147
Number of stars observed for value micrometer-screw	4
Number of single observations	624

Azimuth.

Number of nights observed	4
Number of standard circumpolar stars observed	14
Number of single observations	224

Triangulation in 1874.

Number of stations occupied	5
Number of angles measured	14
Number of stations built	1

SUMMARY FOR THE YEAR.

Triangulation.

Number of stations occupied	13
Number of primary angles measured	50
Number of secondary angles measured	11
Number of results on each primary angle, 40; making in all	2,000

Latitude.

Number of pairs of stars observed	147
Number of observations for one turn of micrometer screw	624

Azimuth.

Number of observations on circumpolar stars	14
Number of results at each observation, 16; making in all	224
Number of stations permanently marked	21

Very respectfully submmitted.

A. R. FLINT,
Assistant Engineer.

Gen. C. B. COMSTOCK,
Superintendent United State Lake-Survey.

5.—*Report of Mr. R. S. Woodward, Assistant Engineer.*

FAYETTE, DELTA COUNTY, MICH.,
June 30, 1874.

SIR: In accordance with your instructions of May 1, 1874, I have the honor to submit the following report in regard to field-work during the season of 1873, office-work during the winter of 1873 and 1874, and field-work thus far for the present season.

May 1, 1873, I was ordered to proceed to the work of reading angles of the triangulation in Wisconsin, assigned to the immediate charge of Assistant Engineer A. R. Flint.

Accordingly, we left Detroit on May 2, and on May 6 began work at Horicon station, near Horicon Village, Wis. My party consisted, besides myself, of Mr. M. Brennan, recorder, and Mr. S. L. Large, observer's attendant.

After completing the work at Horicon, we took the west line of stations of the system, beginning with Lebanon, and occupied in succession stations Lebanon, Delafield, Waterford, Dover, Bristol, Antioch, and Frémont, reaching Palatine, the next station south of Frémont, on August 14.

At this time orders were received to repair to Sheboygan, Wis., and report for duty to Lieut. C. F. Powell, Corps of Engineers. We left Palatine, therefore, August 16, and reached Sheboygan August 18.

Reported to Lieutenant Powell the following day, and received instructions to read the azimuth-angles and make the shore-line corrections at North and South Sheboygan stations. This work was completed August 24, and we left Sheboygan on the 25th, reaching Palatine, Ill., on the 26th. Owing to very unfavorable weather, we were unable to complete the work at Palatine station, though we remained there till September 6. On the latter date, in compliance with instructions from Assistant Flint, we proceeded to Green Bay to work on the triangulation connecting the Wisconsin and Lake Superior systems. We began work on the bay September 8, and between this date and October 15 occupied Little Tail Point, Bruce, and Fort Howard stations. The work progressed slowly, however, on account of foggy and stormy weather. At Little Tail Point nearly a month was consumed. At each of Bruce and Fort Howard only two angles were to be read, but the atmosphere was so continually foggy and unsteady as to render the results obtained rather unsatisfactory.

October 15, we left Green Bay for Palatine, having received orders to return to the triangulation in Illinois. Here again the weather proved very unfavorable.

It was desired to carry the triangulation as far as the shot-tower in Chicago, but very little progress was made up to November 1, when we were ordered to return to the office.

During the entire season, the 10-inch Gambey repeating-theodolite was used. Its reputation as a repeating-instrument has already been established, and needs no comment here.

Mention must be made of the cordial assistance rendered at all times by Messrs. Brennan and Large. To them is due, in a great degree, the general success of the season's work. Mr. Large rendered especially valuable service in setting targets and in flashing. A summary of the season's work in tabular form will be found at the close of the report.

Soon after returning to the office in November last, I was ordered to report to Assistant Engineer E. S. Wheeler. Under his direction, I assisted in making comparisons between the standard bar and yards, in the determination of constants of the base-line apparatus, and computed the length of Keweenaw base from the measurement of 1873. The details of this work will be found in Assistant Engineer Wheeler's reports.

May 5, 1874, I was again ordered to the field, and took passage on board lake-survey steamer Search, in charge of Assistant Engineer A. R. Flint, for Green Bay.

We began work on the triangulation May 13, at Débroux's Bluff station. Since then we have completed the work at Débroux's Bluff, Menomonee, and Burnt Bluff stations.

At Menomonee we carried a secondary system of triangulation four miles up the Menomonee River to connect the triangulation-station with a point on the land-survey correction-line in Wisconsin.

My thanks are due to Col. A. Jacobi, civil engineer, Menomonee, and the Messrs. Van Cleve, civil engineers, Marinette, for assistance rendered in determining a section-corner on the above line.

This season, Mr. E. L. Ferguson has served as recorder for the party, and Mr. S. L. Large as observers' attendant. They have both given valuable aid in the prosecution of the work. In the primary triangulation, the Troughton and Simms 14-inch non-repeating theodolite has been used thus far.

In the secondary work at Menomonee, the Blunt 10-inch theodolite was used.

The former instrument has given excellent satisfaction; the latter will be reported on hereafter.

Below is given a summary of field-work done during the seasons of 1873 and 1874.

Summary of field-work done during 1873 *and* 1874.

1873.

Between May 1 and July 1:		
Number of stations occupied		4
Number of angles measured	primary	15
	auxiliary	5
Between July 1 and November 2:		
Number of stations occupied		9
Number of angles measured	primary	24
	auxiliary	19
Between May 1 and November 2:		
Number of stations occupied		13
Number of angles measured	primary	39
	auxiliary	24

1874.

Between May 5 and July 1:		
Number of stations occupied	primary	3
	secondary	10
Number of angles measured	primary	14
	secondary	27

Very respectfully,

R. S. WOODWARD,
Assistant Engineer.

Gen. C. B. COMSTOCK,
Superintendent U. S. Lake-Survey.

6.—*Report of Lieut. D. W. Lockwood, Corps of Engineers.*

UNITED STATES LAKE-SURVEY STEAMER ADA,
June 30, 1874.

MAJOR: I have the honor to submit the following report of work done by parties under my charge during the fiscal year ending June 30, 1874:

May 10, 1873, I left Detroit in command of the lake-survey steamer Search, with the astronomical parties of Lieutenants Maguire and Powell on board the boat.

Lieutenant Maguire's party was landed at Whitehall, Mich., and Lieutenant Powell's at Clay Banks, (west shore.)

Up to the 7th of June, the crew were engaged in building and repairing stations and cutting out sight-lines along the west shore of Lake Michigan from Clay Banks to Milwaukee. After the last-mentioned date, the off-shore hydrography of the south end of the lake was completed from near New Buffalo to Wind Point, north of Racine.

During the latter part of August, the steamer, in accordance with your instructions, proceeded to Green Bay, and from the time of her arrival there until the close of the season, October 15, the party was engaged in building and repairing the stations required to carry the primary triangulation from Big Bay des Noquet, south to Green Bay City.

The boat arrived at Detroit October 17, 1873. During the winter I was engaged in looking after the plotting of the off-shore soundings, laying up and fitting out the steamers, and in collecting data for a report on methods of shore-line work practiced on the lake-survey, accuracy, &c.

May 5, 1874, I left Detroit in command of the lake-survey steamer Ada, with instructions to build what stations were required at the east end of Lake Ontario, to complete the secondary triangulation of the St. Lawrence, already nearly finished.

In addition to this, my instructions also required me to move, when necessary, the shore-parties, four in number, and supply them. Up to the end of the fiscal year, the following work has been performed: Stations built, 9; one 35-foot, three 25-foot, and five 10-foot center-posts.

In addition, nearly all the stations of last year required repairing, and in most cases marking. Considerable cutting has been done; a secondary base-line near Cape Vincent has been measured.

The secondary triangulation of the St. Lawrence has been completed to the line △ Tibbet's Point— △ Bear Point, and the secondary base at Cape Vincent connected with the line △ Sir John's— △ Carlton. Considerable time has been occupied in supplying and moving shore-parties.

I have the honor to be, very respectfully, your obedient servant,

D. W. LOCKWOOD,
First Lieutenant of Engineers.

Maj. C. B. COMSTOCK,
Corps of Engineers.

7.—*Report of Mr. Henry Custer, Assistant Engineer.*

DETROIT, MICH., *July* 1, 1874.

SIR: Agreeably to your instructions, I have the honor to lay before you a report of the field-work and office-work rendered, the former by the party under my charge during the summer of 1873, the latter by myself and assistants during the winter of 1873–'74 and summer of 1874 up to date.

The party, consisting of twenty-one men, one subassistant, and two recorders, reached Racine City, Wis., the 10th of May. It established its camp near the mouth of Root River. The work in this locality still left unfinished from last season (1872) was continued, and brought to a termination by the 23d of June following. The labors of the party performed here were the following: A triangulation was extended over the entire city of Racine, serving as a base for a minute topographical survey of the city and surroundings, made partly with the plane-table, (when the weather was favorable,) partly with the theodolite.

This triangulation furnished also a base for the termination of some 32 buoys located over what is called "The Racine Reef." A large number of soundings were taken between these buoys, in every conceivable direction, securing an exact definition of the extent and nature of the shoal and reef east of the Racine light-house.

While the undersigned was occupied in the performance of the above labors, Assistant Engineer V. T. McGillycuddy was occupied in making a minute topographical survey around the city-limits of Milwaukee, Wis. Subsequently, a triangulation was also made of this city by myself, and, being very ably assisted by Assistant Engineer V. T. McGillycuddy, this work was terminated with good results during the unprecedentedly short time of only three days.

In addition to the above-mentioned work, azimuth-observations were made this time while Polaris was at its eastern elongation, agreeing perfectly with those made the fall previous at the western elongation of the same star. A shore-line survey of two and a half miles in extent, with the corresponding off-shore soundings and in-shore topography, was also made. This work was necessary to close up the gap between the two terminal points of shore-line survey, namely, first, of our survey of 1872; secondly, of the shore-line survey of Assistant Engineer J. R. Mayer, (Ada station VI.) of 1871, in this direction. A few soundings were also taken in Root River, and extended upstream as far as navigable.

On the 25th of June the party was moved to Waukegan, Ill. Here a suitable camp was found about one mile south from the city, near the lake-shore. Here, as in Racine City, a triangulation was made, furnishing the base for a minute plane-table survey of Waukegan City and surroundings. In addition to this, a shore-line survey was made, extending northward seven miles, to the terminal point of my shore-line survey in 1872; southward it extended some nine and a half miles to the southern limits of the village of Lake Forest.

This survey entailed considerable labor by its necessary corresponding off-shore soundings and in-shore topography. In the vicinity of Waukegan, for instance, the 5-fathom curve could only be reached at a distance of a mile or one and one-half miles from shore. On the 2d of August, the labors of the party, somewhat retarded by rainy weather and considerable sickness among the crew, were terminated for this locality. On the 4th of August the party was moved southward, to the village of Winnetka, Ill. This locality was selected as the most central point between the two limits of the shore-line yet to be surveyed.

The shore-line survey executed here extended northward ten miles and eight and one-half miles southward, to the terminal point of Assistant Engineer J. R. Mayer's shore-line survey of 1872 in this direction.

Corresponding off-shore soundings were made along the whole extent of the shore-line survey. A considerable shoal, extending itself northeast and southeast of the locality known as Grosse Point, was carefully defined by a large number of soundings. A plane-table survey was made by the undersigned of Evanston and North Evanston, based here, as elsewhere, upon a sufficient number of triangulation-points. The in-shore topographical survey along this portion of the lake-shore was most laborious, on account of the unbroken chain of towns and villages situated upon this portion of the lake-shore.

On the 12th of September the labors of the party at this point were terminated. Agreeably to your orders, arrangements had been made with one of the northern transportation-steamers to move the party, boats, and camp-equipage to its new place of labor, the St. Lawrence.

Accordingly, on the 14th of September, the party was brought to Chicago, and there placed on board of the steamer St. Albans, on the eve of sailing for the St. Lawrence.

The party reached Clayton, N. Y., on the 23d of September. On the 24th of September it was taken on board of the United States lake-survey steamer Ada, in command of Captain Livermore, and brought to the new camping-ground, on the northeast shore of Wolfe's Island, in the St. Lawrence. During the stay of the party in this locality, a plane-table survey was made of a portion of Wolfe's Island; the survey extended eastward to the light-house on the east end of the island. A similar survey (plane-table) was made by Assistant Engineer V. T. McGillycuddy, over a portion of Howe's or Sir John's Island. These surveys were not immediately based upon triangulation-points. Their validity was, however, fully established by a subsequent triangulation, made by the undersigned, which verified the plane-table work, and extended itself westward and northward some distance down the Bateau Channel. Altogether about twenty-eight miles of shore-line were surveyed from the camp on Wolfe's Island. The principal bays along this portion of the shore-line of Wolfe's Island were also sounded. On the 1st of November the work was, owing to rough weather setting in, discontinued, the party taken on board the steamer Ada, with orders to store boats and camp-equipage at Clayton, N. Y. This order was subsequently carried out, with, however, the loss of one of our boats, which was wrecked, during a severe gale, while the steamer was on her way to Clayton.

On the 10th of November the steamer Ada reached Detroit with the party on board.

During the winter 1873–'74 the undersigned was occupied in plotting his field-notes and in making the necessary computations. (Very little of this sort of labor had been done in the field.) During the time from December to May 1 the undersigned was assisted by one, oftener two, assistant engineers, whose labors necessitated direction. Since May 1 and up to date the undersigned has continued his labors in the office, but unassisted. The results of all these labors, both in the field and in the office, are stated in detail in the tables which are added to this report, and out of them all the necessary information as to how much has been done and in what manner these surveys have been conducted can be had.

I am, general, very respectfully, your obedient servant,

HENRY CUSTER,
Assistant Engineer.

Gen. C. B. COMSTOCK,
Superintendent United States Lake Survey.

Table showing in detail the amount of work, and nature of it, performed by the party in charge of the undersigned during the season of 1873.

	Miles of shore-line.			Stations set.				Angles read.				Points determined.						Sets of observations.			Computations.							
	Lake.	Inland.	Square miles.	Azimuth.	Shore-line.	Sounding.	Triangulation.	Horizontal.	Vertical.	Repeated angles.	No. of repetitions.	By chain only.	Stadia and compass.	Plane-table	Triangulation.	In altitude and location.	Azimuth posts and marks.	Azimuth.	Time.	Latitude.	Triangles.	Azimuth.	Time.	Latitude.	Points of profile-lines and bluffs.	Buoys set and determined.	Casts of lead.
Shore-line	60.95	3.5	.....	10	126	...	....	1,072	.....	40	166	...	.....	.....	.....	.....	8	...	....	....	...	....	....	....	.....	.....	.....
Topography	.....	....	53.5	...	...	...	....	2,002	572	...	.....	280	7,580	.....	.....	.....	.....	...	....	....	...	....	....	....	.....	.....	.....
Triangulation	.....	...	.....	...	...	....	55	178	.....	495	1,299	...	.....	.....	119	.....	.....	...	....	....	105	....	....	....	.....	.....	.....
Plane-table	.....	....	17.62	...	...	...	....	.....	.....	...	.....	...	.....	*18,000	.....	.....	.....	...	....	....	...	....	....	....	.....	.....	.....
Profile-lines and bluff-altitudes	.....	....	.....	...	...	....	....	.....	.....	...	.....	...	.....	.....	.....	592	.....	...	....	....	...	....	....	....	68	.....	.....
Astronomical work	.....	..	.....	...	...	....	....	.....	.....	...	.....	...	.....	.....	.....	.....	.....	32	7	3	....	32	21	3	.....	.....	.....
Computations	.....	...	.....	...	...	....	....	.....	.....	...	.....	...	.....	.....	.....	.....	.....	...	....	....	...	....	....	....	.....	.....	.....
Lake-soundings	.....	...	.....	...	...	125	....	.....	.....	...	.....	...	.....	.....	.....	.....	.....	...	....	....	...	....	....	....	.....	108	10,756
Harbor-soundings	.....	...	.....	...	...	84	....	.....	.....	..	.....	...	†84	.....	.....	.....	.....	...	....	....	...	....	....	....	.....	.....	360
Total	60.95	3.5	71.12	10	126	209	55	3,252	572	535	1,465	280	7,664	18,000	119	592	8	32	7	3	105	32	21	3	68	108	11,116

* This is only a very approximate estimate, probably largely underestimated. The altitudes taken while surveying with the plane-table are here not given, since they are difficult to ascertain.

† 84 flags for harbor-sounding.

HENRY CUSTER.

Amount of office-work during the winter of 1873–'74 *up to date.*

	Sheets completed.	Sheets partly completed.	Square inches of finished topography.	Square miles of preliminary plotting, on a scale of 1:10000.	Soundings corrected, located, and pointed.	Number of ordinates and abscissæ of points duplicated.	Number of triangles.	Bluff-altitudes and profiles.
Mapping	4	3	913 and *810	53.5	2,705 app.	.....	.....	.....
Computing	.....	.....	.....	.....	.....	†42 and 200	60	235

* 810 square inches of partly-finished topography.

† These 42 ordinates and abscissæ are the co-ordinates of 22 triangulation-points, which were computed.

8.—*Report of Mr. A. C. Lamson, Assistant Engineer.*

OFFICE UNITED STATES LAKE-SURVEY,
Detroit, Mich., June 5, 1874.

SIR: I have the honor to submit the following report of operations of the party under my charge during the season of 1873, together with the office-work done during the winter of 1874.

On May 1, 1873, I received instructions from you to make a reconnoissance on the Detroit River for a base-line for the secondary triangulation.

I was furnished with a steam-launch, and was assisted in the work by Assistant Engineer F. Terry.

A base-line was found on the Michigan Central Railroad, in the neighborhood of Wyandotte, about 6,000 feet long, and was subsequently measured by Assistant Engineer F. M.Towar. Having carried out my instructions, I returned to Detroit May 3. On May 5, under instructions to make a survey of the Detroit River, I embarked, with Assistant Engineer F. Terry and Recorders J. Teeple, Würdemann, and 21 laborers, on board the United States steamer Surveyor, and proceeded down the river, establishing camp on Sugar Island, moving camp in a few days over to Bois Blanc.

The work in this field embraced the survey of Lake Erie in the neighborhood of Bar Point, and the river up as far as Stony Island on the Canadian shore, and up as far as Trenton on the American shore, including the lower end of Grosse Isle and the islands in that locality.

The work on Lake Erie was greatly retarded in consequence of many severe storms experienced during our stay in that locality, also in the displacement of buoys by the almost continuous stream of steamers and sailing-vessels passing in and out the river. In the river the same trouble was found, with the additional disadvantage of swift currents, especially near Stony Island.

On July 25 camp was moved from Bois Blanc to the head of Grosse Isle, and the work carried up the river as far as Ecorse.

On September 9 camp was moved from Grosse Isle to Fort Wayne, and the work carried up the river as far as Eighteenth street, Detroit.

On October 3 camp was moved from Fort Wayne to Belle Isle, and the Detroit River survey connected with the survey of Lake St. Clair. By November 7, at which time camp at Belle Isle was broken up and the party returned to Detroit, the survey of Detroit River was completeh, with the exception of the city-front.

Immediately after the return of the party from the field, Assistant Engineers F. Terry and J. Teeple were ordered by you to survey the city-front, which they accomplished in about ten days, completing the survey of the Detroit River.

On April 1, 1874, Assistant Engineer F. Terry was ordered by you to make a survey of the city of Detroit; subsequently Assistant Engineer J. Teeple was ordered into the field on the same duty. Assistant Engineer Terry's work included the survey east of Woodward avenue, and that of Assistant Engineer Teeple the survey west of Woodward avenue, the work being completed about the 1st of May. The secondary triangulation of the river was commenced by Assistant Engineer Towar, who carried the work from Pointe Mouille up the river as far as Sandwich, when the work was turned over to me.

I established stations up the river and through the city, connecting with the lighthouse on Lake St. Clair, when the secondary triangulation was transfered to Assistant Marr, who completed the work during the winter of 1874.

To Assistant Engineer F. Terry and Recorder J. Teeple I wish to express my thanks for their zeal, ability, and care during the summer's operations. Recorders Würdemann and Wells rendered good service as far as they were capable.

The following is the amount of field-work accomplished during the season:

Field-work.	From May 1 to June 30, 1873.	From July 1 to Nov. 7, 1874.	Total.
Stations built	35	70	105
Sounding-stations	185	371	556
Theodolite-pointings	5,220	10,440	15,660
Theodolite-readings	5,686	11,373	17,059
Lines of soundings	907	1,814	2,121
Casts of lead	26,633	53,266	79,899
Sextant-angles	152	305	457
Buoys	78	157	235
Compass-readings	2	5	7
Observations on Polaris	2	3	5
Square miles of hydrography	18	36	54
Square miles of topography	16	32	48
Shore-lines	42	83	125
Angles measured	.....	.....	10

The following is the amount of office-work done during the winter of 1874:

Square inches of hydrography	2,173
Square inches of topography	1,924
Shore-line traced	125
Points plotted	661
Lines of soundings plotted	2,121
Buoys plotted	235

Very respectfully, your obedient servant,

A. C. LAMSON,
Assistant Engineer.

Maj. C. B. COMSTOCK,
Corps of Engineers, Superintendent United States Lake-Survey.

9.—*Report of Mr. J. R. Mayer, Assistant Engineer.*

MUD BAY, *June* 28, 1874.

SIR: In compliance with your instructions, I have the honor to address you the following report:

Report of the amount of work done by my party from July 11, 1873, to October 21, 1873:

Trigonometrical stations built		46
Sounding-stations built		194
Buoys located		29
Lines sounded		968
Miles of soundings		539
Casts of the lead		22,133
Triangulation	pointings	899
	readings	1,478
Topography	pointings	5,231
	readings	6,650
	vertical angles	1,392
Miles of shore-line		76.5
Miles of roads leveled		25
Square miles of topography		17.3
Square miles of hydrography		18
Meridian observed		1
Base-lines measured		3

The survey was based on a tertiary triangulation made by me, and having for base-line a side of the primary triangulation (△ Dorr—△ Grindstone) given to me before I started for the field. But having discovered that the data was erroneous, being too short

of 280m.25, I was compelled to make an additional work in measuring three small-base-lines, and forming twelve new triangles, which work caused a loss of some fifteen days and checked the progress of the other divisions of the survey so much that the amount of work done for shore-line and soundings during nearly a month was very little. Consequently it would be fair to date the beginning of the survey from the 1st of August, 1873.

Besides that, it has been necessary to exceed your instructions, in order to sketch minutely all the *accidents* of the ground by leveling carefully more points, and tracing the contour-lines 10 feet apart of vertical elevation.

Very respectfully,

J. R. MAYER,
Assistant Engineer.

Maj. C. B. COMSTOCK,
Corps of Engineers, Bvt. Brig. General, U. S. A.

10.—*Report of Mr. F. M. Towar, Assistant Engineer.*

GANANOQUE, ONTARIO, *June* 30, 1874.

MAJOR: I have the honor to submit the following report of the work done by the party under my charge during the fiscal year ending June 30, 1874.

On July 3, 1873, I left Detroit for the St. Lawrence River on board the United States steamer Ada, having with me Assistant Engineer A. T. Morrow, Recorders Russel and Brotherton, and six men.

We arrived at Wellesley Island, St. Lawrence River, on the morning of July 7, where we established the camp.

I proceeded at once to Ogdensburg to recruit the remainder of my party. I accomplished this and returned on July 10.

We remained at this place until September 1, completing the Canada channel from Rockport to Gananoque, a distance of about twelve miles. In this distance there were upward of three hundred islands, grouped together in many instances so thickly as to render the development of their shore-line very difficult.

On September 1 my camp was moved to the American channel, between Clayton and Cape Vincent.

We occupied two camps on this channel, completing it from the foot of Long Island to Tibbitt's Point light-house at the head of the river.

On October 23 we broke up camp for the season, and the party was disbanded. I was then ordered to report to Capt. W. R. Livermore, Corps of Engineers, under whose orders I was engaged until November 10, when we arrived in Detroit.

During the winter-season, my work was plotted on five sheets of antiquarian paper by myself and Assistant Engineer J. Teeple.

I am particularly indebted to Messrs. Morrow and Russel for the prompt and efficient manner in which they performed their duties in the field, and to Mr. Teeple for his assistance in the office.

On May 5, 1874, my party left Detroit on the steamer Ada, I joined them at Cape Vincent on May 9, and we were placed in camp at this place on the following day; since that time we have completed the unfinished shore-line, topography, and hydrography from Gananoque to the head of Howe Island, a distance of twelve miles.

I have been efficiently aided in this work by Messrs. Donovan and Winchell.

Inclosed is a tracing showing the locality of my work for the year.

The shore-line, shaded with carmine, is that which was resurveyed for the location of sounding-stations only; that inclosed with a continuous line shows the shore-line developed and the approximate limit of the topography connected with it.

The following is the amount of work given, in detail, done during the fiscal year:

Field-work.	1873.	1874.	Total.
Lines of sounding	1,643	624	2,267
Casts of lead	32,767	13,615	46,382
Square miles of hydrography	47	34	81
Miles of shore-line	126	68	194
Theodolite-pointings	11,764	6,502	18,266
Theodolite-readings	15,871	7,439	23,310
Square miles of topography	38	14½	52½
Altitudes determined	3,054	565	3,619
Triangulation-stations built	51	55	106
Compass-readings	15	6	21
Sounding-stations built	820	1,185	2,005
Observations for meridian	9	2	11
Miles of shore-line for locating sounding-stations	.....	29	29

During the winter of 1873 and 1874, the shore-line topography and hydrography were plotted, and ninety-three triangles were computed.

Very respectfully, your obedient servant,

F. M. TOWAR,
Assistant Engineer.

Maj. C. B. COMSTOCK,
Corps of Engineers, U. S. A.

11.—*Report of Lieut. Edward Maguire, Corps of Engineers.*

DETROIT, MICH., *July* 1, 1874.

MAJOR: I have to submit the following report of work accomplished by me during the season ending June 30, 1874.

In compliance with your instructions, I left Detroit with my party May 9, 1873, and arrived at Whitehall, Mich., May 12, moving to Clay Banks station the same day.

At this station I was unable to do any work, on account of bad weather, until the 31st of May. The work here consisted of observations for azimuth, latitude, and horizontal angles. At Duck Lake, the horizontal angle was read.

At Douglass, the work consisted of observations for azimuth, latitude, and horizontal angle.

At South Haven station, the horizontal angle was read and latitude observed for.

At Frankfort, observations for azimuth were taken; station Frankfort was connected with station Point Betsey.

I arrived at St. Joseph October 12, and remained there until November 19, without being able to do any work at all.

The whole amount of work accomplished is as follows:

Azimuth.

	Results
Frankfort	3
Clay Banks	3
Douglass	5
Total	11

Latitude.

	Pairs
Clay Banks	37
Douglass	58
South Haven	54
Total	149

Horizontal angles.

	Readings
Frankfort	36
Clay Banks	172
Duck Lake	56
Douglass	122
South Haven	64
Total	452

During the winter I was engaged in the computation of the field-notes; the following are the results:

Horizontal angles.

		Prob. error.
Little Point Sable—Clay Banks—Duck Lake	172° 53′ 10″.65	0″.11
Clay Banks—Duck Lake—Twin Sisters	175° 38′ 51″.86	0″.26
Twin Sisters—Douglass—South Haven	192° 34′ 21″.81	0″.43
Douglass—South Haven—St. Joseph	200° 52′ 10″.17	0″.33

Latitude of △ stations.

		Prob. error.
Clay Banks	43° 30′ 23″.01	0″.19
Douglass	42° 38′ 11″.62	0″.16
South Haven	42° 16′ 13″.48	0″.17

Observed azimuths.

Of △ Point Betsey from △ Frankfort..... 181° 16′ 28″.20
Of △ Little Point Table from △ Clay Banks..... 171° 02′ 05″.77
Of △ Twin Sisters from △ Douglass..... 180° 40′ 49″.47

I am, major, very respectfully, your obedient servant,

EDWD. MAGUIRE,
Lieutenant of Engineers, U. S. A.

Maj. C. B. COMSTOCK,
Corps of Engineers, U. S. A.

12.—*Report of Lieut. C. F. Powell, Corps of Engineers.*

LAKE-SURVEY ASTRONOMICAL STATION,
St. Johns, Mich., July 30, 1874.

MAJOR: I have to submit the following report of my work on the survey since May 7, 1873, the date of the previous report, to June 30, 1874.

FIELD-WORK, 1873.

At the time of the last report I had been assigned to the continuation of the latitude and azimuth work on the west shore of Lake Michigan, which I had begun the previous season. This work, when completed, was to give the latitudes and longitudes of a series of points, the extreme ones being near Sturgeon Bay, Wisconsin, and at or near Milwaukee, on which to base the map of the part of Lake Michigan lying between these points.

My party included one recorder, one cook, one observatory-attendant, two flashers, and three laborers. Later in the season Assistant Engineer R. S. Woodward, with a small party, reported for temporary duty, upon the completion of which he was relieved.

Portage station, near Sturgeon Bay, had been located in 1871 by Captain Lee, from the Green Bay triangulation. Its latitude had also been determined by me in 1872. I therefore proceeded to Clay Banks, the first station south from Portage, where the party was landed from the survey-steamer Search on May 16.

From Clay Banks I occupied in succession the stations Kewaunee, Two Rivers Point, Point Creek, Ada I, Fox's Point, and Milwaukee court-house.

The party and camp were moved from Clay Banks by small boats, from Kewaunee by small boat and wagon, and thereafter by steamer or rail.

The horizontal angle was read at each station; latitude observed where I had not taken it the previous year, excepting at Milwaukee court-house, where it was not required; observations for azimuth made at Clay Banks, Point Creek, and Fox's Point, and connections established with the survey astronomical posts of 1866 at Clay Banks and Two Rivers Point. The Kewaunee latitude post of 1866 had been destroyed.

Connections were also made with one or more points of the shore-line survey; topographical sketches drawn and underground and surface marks placed, according to general instructions governing parties occupying primary-triangulation stations.

Observations in two different sets, for the determination of the value of a division of micrometer and levels of myzenith-telescope, were made at Fox's Point.

Mr. Woodward occupied the North and South Sheboygan stations, read the horizontal angle, connected with the latitude-post of 1866 at North Sheboygan, made other required connections, and placed the station-marks at both places.

In order to connect the work with the Wisconsin triangulation, angles were read at Fox's Point to three points in Milwaukee fixed by the triangulation.

The data of my work and the triangulation latitudes will afford a comparison of longitudes brought from Green Bay by different methods and different routes.

To obtain a comparison of azimuths, angles were read at the dome of the Milwaukee court-house from Fox's Point to the triangulation stations at Lisbon and New Berlin.

The Kewaunee, Point Creek, North Sheboygan, and Ada I stations were built during the summer. The first two were placed on new sites, and were required to break the long lines north and south from Two Rivers Point. The station at North Sheboygan was necessary to replace one destroyed, and that of Ada I to gain a greater elevation than afforded by the off-shore hydrographic station of 1871 over the same station mark. The second and third stations named were built by Lieutenant Lockwood's steamer party.

The field-work was finished on October 9.

The instruments used were the 20-inch Oertling theodolite No. 2562, of late issue; and the old 24-inch Würdemann zenith-telescope No. 1. The defeects of the Oertling instru-

ment are well known. The zenith-telescope had been repaired thoroughly the previous winter, and was ingood condition.

Mr. Horace Holmes, recorder, merits commendation for the interest shown in the work, and assistance rendered in station-building, making connections, and posting flashers.

OFFICE-WORK, 1873 AND 1874.

During the winter I was engaged upon the computation of the field-work, in completing that for the season of 1872, and reworking the latitudes of 1872, using later adopted values of instrumental constants and omitting all pairs not independent or containing stars not given in Safford's catalogue, 1875. Except the reference of azimuths to the same line and adoption of mean result, and consequently, the computation of final longitudes, all the work has been re-computed independently and compared. The azimuth stations have been plotted, and the co-ordinates therefrom of the latitude and azimuth posts indicated, upon the detailed survey sheets.

The values obtained for instrumental constants of the zenith telescope will be found in my record book of latitude observations, 1873. Other results are shown in the tables following. The "mean" result for latitude is the arithmetical mean, and from that the probable errors have been computed. The want of assistance and pressure of other duties prevented the computation of final result and probable error by a more rigid method.

Readings and results in the column "Number of readings or results" refer respectively to the non-repeating Oertling theodolite and repeating Gambey and Würdemann instruments. A result is the mean of five readings in each position of the telescope.

Attention will be drawn to the Point Creek azimuth on account of its variance from the four others and their close agreement. At Point Creek, the light of the Sheboygan light-house was read to at night and the tower during day-time. Care was taken to prevent the effect of phase to see that the light was in the axis of the tower and to determine the reduction to station from azimuth-post. The computed distance, Point Creek—North Sheboygan; measured distance, North Sheboygan—Light-House; and one reading of the included angle, give the angle at Point Creek to within less than 1" of that observed. In obtaining the mean result, the Point Creek azimuth has been used with full weight.

The Wisconsin triangulation not having been worked up, the comparison of longitudes and azimuths at Milwaukee cannot now be made.

LATITUDES PREVIOUSLY REPORTED.

Station.	Year.	Number of results.	Latitudes.	Reduction from re-computation.	Reduction to △	Latitude of △	Observer.
			° ′ ″	″	″	″	
Portage	1871	.....	44 48 54.780	.....	.....	54.78	(*)
Do	1872	47	55.076	− 0.060	+ 3.397	58.41	C. F. P.
			Adopted	.....	.....	56.60	
Clay Banks	1866	147	44 41 15.310	.....	+ 3.879	19.19	S. W. R.
Do	1872	47	35.300	− 0.044	−15.276	19.98	C. F. P.
			Adopted	.....	.....	19.45	
Two Rivers Point	1866	147	44 11 34.785	.....	+29.613	64.40	S. W. R.
Do	1872	27	12 04.691	− 0.115	− 0.005	04.57	C. F. P.
			Adopted	.....	.....	04.46	
North Sheboygan	1866	82	43 45 54.130	.....	− 1.070	53.06	S. W. R.
South Sheboygan	1872	36	43 41 01.498	− 0.126	− 0.090	01.28	C. F. P.

* Reduced from Captain Lee's triangulation.

LATITUDES, 1873.

Station.	Date.	Number of pairs.	Latitudes.	Probable error.	Reduction to △	Latitude of △	Observer.
			° ′ ″	″	″	″	
Kewaunee	June 30	24	44 25 41.075				C. F. P.
Do	July 2	18	40.744				Do.
Do	July 4	23	41.320				Do.
Do	July 5	23	41.266				Do.
Mean			41.122	±0.100	+0.003	41.13	
Point Creek	Aug. 2	23	43 57 57.787				C. F. P.
Do	Aug. 3	22	58.186				Do.
Do	Aug. 4	28	58.375				Do.
Do	Aug. 5	28	58.729				Do.
Mean			58.295	±0.095	+0.558	58.85	
Sheboygan light-house			43 45 50.360				(*)
Lutheran church, Sheboygan			43 45 12.880				(†)
Ada I	Sept. 4	19	43 29 18.574				C. F. P.
Do	Sept. 8	21	18.730				Do.
Do	Sept. 10	20	18.289				Do.
Do	Sept. 11	21	19.041				Do.
Mean			18.677	±0.088	+0.02	18.70	
Fox's Point	Sept. 22	19	43 10 13.438				C. F. P.
Do	Sept. 23	8	13.218				Do.
Do	Sept. 25	22	13.317				Do.
Do	Sept. 26	26	13.730				Do.
Do	Sept. 27	22	13.068				Do.
Mean			13.353	±0.080	−0.088	13.27	

* Reduced from North Sheboygan. † Reduced from North Sheboygan and Point Creek.

HORIZONTAL ANGLES.

Angles.	Year.	Number of readings or results.	Mean.	Probable error.	Direction.	Observer.	Instrument.
			° ′ ″	″			
Azimuth-mark 1872—Clay Banks—Portage.	1872	38	3 05 56.89	±0.54	L	C. F. P.	Oertling theodolite 2562.
Portage—Clay Banks—azimuth-mark 1873.	1873	52	5 06 11.43	±0.33	L	..do...	Do.
Azimuth-mark 1873—Clay Banks—Kewaunee.	1873	64	178 24 04.67	±0.39	L	..do...	Do.
Clay Banks—Kewaunee—Two Rivers Point.	1873	60	199 54 08.25	±0.28	L	..do...	Do.
Kewaunee—Two Rivers Point—Point Creek.	1873	54	150 54 29.72	±0.30	L	..do...	Do.
Two Rivers Point—Point Creek—North Sheboygan.	1873	78	149 22 06.47	±0.24	R	..do...	Do.
North Sheboygan—Point Creek—Sheboygan light-house.	1873	76	0 09 28.70	±0.16	R	..do...	Do.
Sheboygan light-house—Point Creek—Lutheran church, Sheboygan.	1873	18	3 20 30.50	±0.34	R	..do...	Do.
Point Creek—North Sheboygan—South Sheboygan.	1873	16	175 02 21.41	±0.27	L	R. S. W	Gambey theodolite 1, 10-inch limb.
South Sheboygan—North Sheboygan—Lutheran church.	1873	4	45 28 46.93	±0.58	R	..do...	Do.
North Sheboygan—South Sheboygan—Ada I.	1873	16	166 02 05.38	±0.23	L	..do...	Do.

HORIZONTAL ANGLES—Continued.

Angles.	Year.	Number of readings or results.	Mean.	Probable error.	Direction.	Observer.	Instrument.
			° ′ ″	″			
North Sheboygan—South Sheboygan—azimuth-mark.	1872	32	0 22 17.66	±0.57	R	C. F. P.	Oertling theodolite 2562.
South Sheboygan—Ada I—Fox's Point.	1873	60	173 13 14.00	±0.52	R	..do...	Do.
Ada I—Fox's Point—Milwaukee court-house.	1873	54	176 10 44.24	±0.30	R	..do...	Do.
Milwaukee court-house—Fox's Point—South Milwaukee.	1873	30	14 47 34.49	±0.37	L	..do...	Do.
Milwaukee court-house—Fox's Point—Catholic cathedral, Milwaukee.	1873	24	0 19 19.84	±0.23	L	..do...	Do.
Catholic cathedral, Milwaukee—Fox's Point—Episcopal cathedral, Milwaukee.	1873	24	0 43 39.85	±0.36	L	..do...	Do.
Fox's Point—Milwaukee court-house—Lisbon.	1873	2	74 29 11.64	±1.84	L	H. H..	Würdemann theodolite 23, 6-inch limb.
Fox's Point—Milwaukee court-house—New Berlin.	1873	4	116 31 40.67	±0.85	L	C. F. P.	Do.

AZIMUTHS.

[Observer, C. F. P.—Instrument, Oertling theodolite 2562.]

Station.	Date.	Number of readings.	Star.	Mean.	Direction.	Reduction to △.	Azimuth west of south, △, — mark.
	1872.			° ′ ″			
Clay Banks	Aug. 26	6	Polaris, near e. e	27 43 09.97	R		
Clay Banks	Aug. 29	4	....do	17.76			
Clay Banks	Aug. 30	4	....do	20.07			
Clay Banks	Aug. 31	12	....do	16.72			
Clay Banks			Mean	15.84		″ —133.57	° ′ ″ 207 41 02.27
	1873.						
Clay Banks	June 4	10	Polaris, near e. e	19 29 47.00	R		
Clay Banks	June 7	10	λ Ursæ Minoris, near e. e	51.25			
Clay Banks	June 7	10	Polaris, near e. e	51.16			
Clay Banks	June 11	10	λ Ursæ Minoris, near e. e	48.80			
Clay Banks			Mean	49.55		— 54.50	199 28 55.05
Point Creek	Aug. 7	4	δ Ursæ Minoris, between w. e. and c.	180 26 38.55	L		
Point Creek	Aug. 7	8	Polaris, near e. e	24.06			
Point Creek	Aug. 9	10	....do	27.21			
Point Creek	Aug. 10	10	....do	24.37			
Point Creek	Aug. 12	14	....do	28.36			
Point Creek			Mean	26.83		0.00	359 33 33.17
	1872.						
South Sheboygan	Sept. 19	4	Polaris, near e. e	4 43 32.55	R		
South Sheboygan	Sept. 25	4	....do	38.18			
South Sheboygan	Oct. 3	4	....do	22.98			
South Sheboygan	Oct. 4	8	....do	32.41			
South Sheboygan			Mean	31.71		+ 8.40	184 43 40.11
	1873.						
Fox's Point	Sept. 30	8	Polaris, near e. e	172 23 47.35	L	0.00	7 36 12.65

AZIMUTHS REFERRED TO LINE POINT CREEK △—NORTH SHEBOYGAN △.

Station.	Year.	Number of results.	Number of readings.	Azimuths west of south.
				° ′ ″
Clay Banks	1872	4	26	359 24 15.47
Clay Banks	1873	4	40	16.57
Point Creek	1873	5	46	04.47
South Sheboygan	1872	4	20	15.65
Fox's Point	1873	1	8	15.73
				Adopted ...12.62

LONGITUDES WEST FROM GREENWICH.

Station.	Longitude.	
	° ′ ″	
Portage △	87 16 57.81	Reduced from Captain Lee's triangulation.
Clay Banks △	21 51.72	
Kewaunee △	30 16.31	
Two Rivers Point △	30 37.69	
Point Creek △	41 57.72	
North Sheboygan △	41 47.29	
Sheboygan Light-house	41 50.01	
Lutheran Church, Sheboygan	42 51.44	
South Sheboygan △	42 17.99	
Ada I △	47 37.58	
Fox's Point △	52 55.51	

FIELD-WORK, 1874.

For this season I was instructed to determine the latitude and telegraphic longitude of certain points in the interior of Michigan. Observations for personal equation with Lieutenant Maguire were taken at the Detroit observatory.

I left Detroit May 13. Since that time and up to June 30 Pontiac and Lapeer stations have been occupied and the work completed at both places.

Very respectfully, your obedient servant,

CHAS. F. POWELL,
First Lieutenant Engineers.

Maj. C. B. COMSTOCK,
Corps of Engineers, U. S. A.

APPENDIX B.—ASTRONOMICAL DETERMINATION OF POINTS IN THE INTERIOR OF ILLINOIS AND WISCONSIN.

Report of Mr. O. B. Wheeler, Assistant Engineer.

OFFICE U. S. LAKE-SURVEY,
Detroit, Mich., May 15, 1874.

SIR: I have the honor herewith to submit a report on the astronomical determination of points in the interior of Illinois and Wisconsin. The object was to furnish the geological survey of Wisconsin with data for correcting the maps projected from the public-land surveys.

The points determined were two on the fourth principal meridian, the one the State Line between Illinois and Wisconsin near Galena, Ill., and the other near Valley Junction, Wis. Also there were determined, by trigonometrical transfer from the astronomical station at Valley Junction, points on the correction-line between townships 20 and 21 north, and, from a former astronomical station at St. Paul, Minn., points on the correction-line between townships 30 and 31 north, near range 19 west.

The field-observers were Prof. S. W. Robinson, of Illinois Industrial University, and Assistant Engineer T. W. Wright. Professor Robinson made all the time observations in connection with the longitude. The observations at Detroit in connection with Galena and Valley Junction for differences of longitude were made by myself.

The instruments used at Detroit, and the pier upon which the transit was mounted, were the same as noted in Appendix F, United States lake-survey annual report for 1871.

The instruments were the Troughton & Simms transit, 42-inch focal length, and clock and chronograph respectively Nos. 184 and 216 Bond & Son. The instruments used in the field were the combined transit and zenith-telescope Pistor & Martins, Berlin, dated 1849, of 26 inches focal length, and mean-time chronometer Dent 2096.

DIFFERENCE OF LONGITUDE.

A list of stars from the American Ephemeris and the standard catalogue of 539 stars of the German Astronomical Society was prepared to be used by both observers.

This list was arranged as follows:

Level.
Polar Star, (over part of the wires.)
Reversal.
Polar Star, (wires same as before reversal.)
Level.
Five time-stars.
Level.
Reversal.
Level.
Five time-stars.
Level.
Polar Star, (over part of the wires.)
Reversal.
Polar Star, (wires same as before reversal.)
Level.
Transmission of signals.

The remainder of the list was identically arranged with that before the transmission of signals. Thus two time determinations were made on each night at each station, and the transmission of signals came between the two.

The transmission of signals was as follows:

(1.) Field-station breaks for one minute on main line in coincidence with mean-time chronometer, making two breaks at zero seconds, and omitting to break on the 10, 20, 30, 40, and 50 second ticks.

(2.) Detroit clock (sidereal with automatic break-circuit) is switched into the main line for seven minutes; two breaks indicate the zero second, and the 10, 20, 30, 40, and 50 second ticks are cut out.

(3.) Detroit sends arbitrary signals for two minutes, breaking twice at the zero second, and making the signals approximately at 10, 20, 30, 40, and 50 seconds.

(4.) Field-station sends arbitrary signals for two minutes, breaking twice at the zero second, and making the signals approximately at 10, 20, 30, 40, and 50 seconds.

(5.) Same as (2).

All the signals were recorded on the Detroit chronograph. The field-observer observed coincidences of sidereal clock with mean-time chronometer during operations (2) and (5), and also noted the times of all the signals of operations (3) and (4).

In the reduction of the observations, the method of high and low stars was used. Fifteen wires were observed at Detroit, but only five reduced on any time-star, since only five were observed in the field. Observations recorded from the mean-time chronometer were treated as follows:

An epoch was chosen, being an even hour on the face of the mean-time chronometer, and each record from the mean-time chronometer was corrected for the change due to the increase of sidereal interval on mean-time interval for the space of time between the epoch and the record. This changes Dent (mean) to what we call Dent (sidereal.) But Dent (sidereal) still has a rate on sidereal time, and we determine this rate either by comparing its errors in the earlier and later parts of the night, or by comparing the rate of the clock, found by means of its errors, with the rate of Dent (sidereal) on the clock, as determined by coincidences. We have adopted the latter method of determining this rate, since essentially it is only the rate of one clock on the other that is required.

The mean of all the errors of Dent (sidereal) as given by fundamental time stars is taken, and also the mean of the right ascensions of the stars used. To this mean error we apply the correction for rate, reckoning from the sidereal time of the former assumed epoch to the time of the mean of the right ascensions of the stars used. This gives the error of Dent (sidereal) at the assumed epoch. In the following tables, Δt stands for error of clock or chronometer where no account has been taken of rate, and Δt_0 stands for the same corrected for rate. When the clock or chronometer is slow, the sign of the correction is positive, and when they are gaining the rate is negative.

Tables 1, 2, 3, and 4 give the individual results for time for both the Detroit and field-

stations, the mean results for error of the Detroit clock, and the rate of the Detroit clock. The error and deduced rate of Dent (sidereal) are shown in tables 5, 6, and 7. Tables 5 and 6 give the combination of results and the differences of longitude uncorrected for personal equation. Table 7 gives the results of personal equation from observations made at Detroit. The same instruments, method of observation and reduction, were used in determining the personal equation as were employed in the longitude-work, the field-transit being mounted in the Detroit observatory five feet to the west of the Detroit transit. A large range in the results for personal equations will be noticed. The results indicate that the relative personal equation was increasing during the season.

This supposition would account, perhaps, for the gradually diminishing values for longitude in the four nights at Galena.

It is thought best, however, to combine the results in a single result, in the following manner: On September 18, only four time stars were observed, and this night's result should have but little weight. September 16 is combined with September 18, giving the former four times the weight of the latter; then this result is combined with the mean of July 5 and July 6, giving this mean twice the weight of the result from September 16 and September 18. The result thus obtained is $0^s.272$, which, corrected for the difference of longitude of the two transit-instruments ($0^s.005$), gives—

$$\text{S. W. R.} - \text{O. B. W.} = -0^s.277$$

Table 5 gives for a difference of longitude between Detroit and Galena astronomical stations uncorrected for personal equation—

$$29^m\ 30^s.958$$

which, corrected for personal equation, gives—

$$\text{Galena west from Detroit} = 29^m\ 31^s.23$$

Table 6 gives for a difference of longitude between Detroit and Valley Junction as tronomical stations, uncorrected for personal equation—

$$29^m\ 26^s.101$$

which, corrected for personal equation, gives—

$$\text{Valley Junction west from Detroit} = 29^m\ 26^s.38$$

TABLE 1.—*Individual results for error of clock at Detroit and error of chronometer at Galena mean results at Detroit and rate of the Detroit clock.*

Name of star.	July 11.		July 12.	
	Δ *t* of clock.	Δ *t* of Dent sid.	Δ *t* of clock.	Δ *t* of Dent sid.
	m. s.	*h. m. s.*	*m. s.*	*h. m. s.*
1 Aquilæ	−3 14.46	+6 45 48.85	−3 16.12	+6 49 43.04
α Lyræ			16.41	43.22
110 Herculis			16.32	43.25
β Lyræ	14.71	49.04	16.55	43.06
61 Serpentis			16.40	43.04
ε Aquilæ			16.42	42.97
ξ Aquilæ	14.53	48.99		
ω Aquilæ			16.59	43.19
δ Aquilæ	14.78	48.83	16.52	42.94
κ Aquilæ	14.77	48.74	16.49	42.79
Aquilæ	14.82	48.90	16.49	43.20
Mean	−3 14.678	+6 45 48.892	−3 16.431	+6 49 43.069
ζ Cygni				
1 Pegasi				
β Aquarii				
ξ Aquarii	−3 14.80	+6 45 48.57	−3 16.54	+6 49 42.53
ε Pegasi	14.79	48.68	16.54	42.94
μ Capricorni	14.44	48.43		
20 Pegasi				
α Aquarii	14.57	48.58		
θ Pegasi				
θ Aquarii	14.51	48.58		
γ Aquarii	14.59	48.50		
π Aquarii	14.65	48.51		
Mean	−3 14.621	+6 45 48.550	−3 16.540	+6 49 42.735
Hourly rate of clock	+ 0.0201		− 0.0421	
Adopted rate of Dent sidereal from comparisons with clock		− 0.0665		− 0.1249

TABLE I.—*Individual results for error of clock, &c.*—Continued.

Name of star.	July 21.		July 22.	
	Δ *t* of clock.	Δ *t* of Dent sid.	Δ *t* of clock.	Δ *t* of Dent sid
	m. *s.*	*h.* *m.* *s.*	*m.* *s.*	*h.* *m.* *s.*
1 Aquilæ	−3 41.94	+7 24 39.34	−3 44.07	+7 28 33.24
α Lyræ	42.03	39.52	44.28	33.45
110 Herculis	41.99	39.56	44.13	33.44
β Lyræ	42.20	39.38	44.32	33.42
θ¹ Serpentis	42.10	39.31	44.22	33.36
ε Aquilæ	42.12	39.27	44.22	33.32
ζ Aquilæ	42.20	39.21	44.34	33.15
ω Aquilæ	42.31	39.17	44.44	33.09
δ Aquilæ	42.25	39.33	44.38	33.08
κ Aquilæ				
γ Aquilæ	42.19	39.25	44.31	33.03
Mean	−3 42.133	+7 24 39.335	−3 44.271	+7 28 33.254
ζ Cygni	−3 42.42	+7 24 39.16	−3 44.65	+7 28 32.91
1 Pegasi	42.43	39.29		
β Aquarii	42.17	39.19	44.45	33.11
ξ Aquarii	42.25	39.10		
ε Pegasi	42.33	39.23	44.51	33.11
μ Capricorni	42.23	39.48	44.46	32.99
20 Pegasi	42.50	39.32	44.73	33.06
α Aquarii	42.36	39.19	44.44	32.83
θ Pegasi	42.39	39.22	44.59	32.97
θ Aquarii	42.32	39.33		
γ Aquarii	42.40	39.15	44.57	32.79
π Aquarii	42.26	39.16	44.66	32.97
Mean	−3 42.338	+7 24 39.235	−3 44.562	+7 28 32.973
Hourly rate of clock	− 0.0720		− 0.1006	
Adopted rate of Dent sidereal from comparisons with clock		− 0.0745	a.	+ 0.0355

TABLE 2.—*Individual results for error of clock at Detroit, and error of chronometer at Valley Junction; mean result at Detroit, and rate of Detroit clock.*

Name of star.	August 6.		August 8.	
	Δ *t* of clock.	Δ *t* of Dent sid	Δ *t* of clock.	Δ *t* of Dent sid.
	m. *s.*	*h.* *m.* *s.*	*m.* *s.*	*h.* *m.* *s.*
θ Aquilæ			−4 36.85	+8 34 57.81
α_2 Capricorni	−4 30.34	+8 27 11.55	36.92	57.79
π Capricorni			36.95	57.88
Delphini	30.63	10.89	37.25	57.91
α Cygni			37.13	57.85
γ_2 Delphini	30.91	10.98	37.23	57.69
μ Aquarii	30.79	10.94	37.19	57.52
2 Vulpeculæ	30.89	10.97	37.18	57.71
ν Cygni	30.92	11.07	37.26	57.69
1, Cygni			37.32	57.71
ζ Cygni	30.71	11.21	37.31	57.61
Mean	−4 30.741	+8 27 11.030	−4 37.145	+8 34 57.735
ζ Pegasi	−4 30.51	+8 27 10.64		
λ Pegasi	30.66	10.93		
λ Aquarii	30.51	10.68		
α Pegasi	30.70	10.72	−4 37.46	+8 34 57.47
θ Piscium	31.07	10.99	37.73	57.37
ι Piscium	30.95	10.69	37.61	57.39
ω Piscium	31.05	10.48	37.62	57.37
α Andromedæ	31.29	10.73	37.71	57.40
Mean	−4 30.843	+8 27 10.732	−4 37.626	+8 34 57.409
Hourly rate of clock	− 0.0400		− 0.1644	
Adopted rate of Dent sidereal from comparisons with clock		− 0.0614		− 0.1315

TABLE 3.—*Personal equation:—Individual results for error of clock and chronometer at Detroit; mean result for error of clock and rate of clock.*

Name of star.	July 5.		July 6.	
	Δ *t* of clock.	Δ *t* of Dent sid.	Δ *t* of clock.	Δ *t* of Dent sid.
	m. s.	*h. m. s.*	*m. s.*	*h. m. s.*
ζ Ophiuchi			− 3 11.59	+ 6 55 29.01
μ Herculis			12.27	28.88
a^1 Herculis			11.94	28.71
α Ophiuchi			11.92	28.79
μ Herculis			11.93	29.00
1 Aquilæ	− 3 11.73	+ 6 51 44.25	11.70	28.62
α Lyræ			11.98	28.72
β Lyræ	11.76	44.27	12.18	28.64
ζ Aquilæ	11.73	44.03		
d Sagittarii	11.65	44.07		
δ Aquilæ	11.72	44.11		
κ Aquilæ	11.72	44.18		
γ Aquilæ	11.57	43.98		
α Aquilæ	11.52	44.29		
a^2 Capricorni	11.55	44.43		
Mean	− 3 11.661	+ 6 51 44.179	− 3 11.939	+ 6 55 28.796
γ Aquilæ			− 3 11.94	+ 6 55 28.79
a^2 Capricorni			11.77	28.36
π Capricorni			11.59	28.54
β Aquarii	− 3 11.66	+ 6 51 43.99		
Aquarii	11.65	44.08		
μ Capricorni	11.42	43.92		
α Aquarii	11.48	44.04		
θ Aquarii	11.39	44.20		
π Aquarii	11.54	44.25		
Mean	− 3 11.523	+ 6 51 44.080	− 3 11.767	+ 6 55 28.563
Hourly rate of clock	+ 0.0537		+ 0.0717	

TABLE 4.—*Personal equation:—Individual results for errors of clock and chronometer at Detroit; mean result of clock and rate of clock.*

Name of star.	September 16.		September 18.	
	Δ *t* of clock.	Δ *t* of Dent sid.	Δ *t* of clock.	Δ *t* of Dent sid.
	m. s.	*h. m. s.*	*m. s.*	*h. m. s.*
θ Aquilæ	−5 33.02	+11 35 32.16		
a^2 Capricorni	33.05	32.22		
π Capricorni	33.07	32.20		
ε Delphini	33.22	32.25		
α Cygni	33.75	32.46		
γ^2 Delphini	33.43	32.39		
μ Aquarii	33.27	32.25	−5 33.43	+11 43 19.68
32 Vulpeculæ	33.42	32.31	33.54	19.62
ν Cygni	33.57	32.36	33.52	19.56
61^1 Cygni	33.58	32.46		
ζ Cygni	33.55	32.27		
β Aquarii			33.87	19.63
Mean	−5 33.357	11 35 32.303	−5 33.590	+11 43 19.623
λ Pegasi	−5 33.39	+11 35 32.21		
λ Aquarii	33.10	32.28		
α Pegasi	33.28	32.16		
θ Piscium	33.17	31.97		
Mean	−5 33.235	+11 35 32.155		
Hourly rate of clock	+ 0.0526		+ 0.0530	

TABLE 5.—*Combination of results for difference of longitude between Detroit (Mich.) and Galena (Ill.) astronomical stations.*

Date, 1873	July 11.	July 12.	July 21.	July 22.
	h. m. s.	h. m. s.	h. m. s.	h. m. s.
Epoch of reference for Dent, (mean)	11 00 00	11 00 00	10 00 00	10 00 00
Mean Δt of clock before signals	− 3 14.678	− 3 16.431	− 3 42.133	− 3 44.271
at Detroit local sidereal time	19 07 08.5	18 59 11.	18 56 08.4	18 56 08.4
Mean Δt of clock after signals	− 3 14.621	− 3 16.540	− 3 42.338	− 3 44.562
at Detroit local sidereal time	21 56 58.3	21 34 30.	21 47 11.7	21 49 52.7
Rate of clock from its Δt's	+ 00.0201	− 00.0421	− 00.0720	− 00.1086
Mean Δt of Dent sidereal for whole night	+ 6 45 48.708	+ 6 49 43.013	+ 7 24 39.281	+ 7 28 33.121
at Galena, Ill., local sidereal time	20 38 35.'4	19 25 04.	20 29 26.6	20 18 26.2
Coincidence observed at Galena: Dent sidereal	13 20 49.904	13 44 00.619	12 46 53.090	12 44 94.184
Clock	20 39 24.333	21 06 31.000	20 44 45.500	20 46 12.509
Dent sidereal	13 48 32.227	13 56 19.136	12 59 05.590	13 11 33.374
Clock	21 07 06.666	21 18 49.500	20 56 58.000	21 13 18.250
Rate of Dent sidereal on clock, (by coincidences)	− 00.0866	− 00.0828	− 00.0025	+ 00.1361
Rate of Dent sidereal by clock's Δt's and coincidences	− 00.0665	− 00.1249	− 00.0745	+ 00.0355
Δt_0 of Dent sidereal at coincidence	+ 6 45 48.743	+ 6 49 42.870	+ 7 24 39.303	+ 7 28 33.118
True sidereal time of coincidences at Galena	20 06 38.647	20 33 43.489	20 11 32.393	20 12 57.302
Δt_0 of clock at same coincidence	− 3 14.648	− 3 16.518	− 3 42.259	− 3 44.449
True sidereal time of coincidence at Detroit	20 36 09.685	21 03 14.482	20 41 03.241	20 42 28.051
Difference of longitude by signals from Detroit to Galena	29 31.038	29 30.993	29 30.848	29 30.749
Means of comparisons from Detroit chronograph: Dent sidereal	13 15 52.259	13 32 01.906	12 42 39.146	12 39 25.117
Clock	20 34 26.790	20 54 32.317	20 40 31.687	20 41 13.568
Δt_0 of Dent sidereal at comparison	+ 6 45 48.747	+ 6 49 42.895	+ 7 24 39.308	+ 7 28 33.115
True sidereal time of comparison at Galena	20 01 41.006	20 21 44.801	20 07 18.454	20 07 58.232
Δt_0 of clock at comparison	− 3 14.650	− 3 16.510	− 3 42.254	− 3 44.441
True sidereal time of comparisons at Detroit	20 31 12.140	20 51 15.807	20 36 49.433	20 37 29.147
Difference of longitude by signals from Galena to Detroit	29 31.134	29 31.006	29 30.979	29 30.915
Mean difference of longitude, (signals in both directions)	29 31.086	29 31.000	29 30.914	29 30.832

TABLE 6.—*Combination of results for difference of longitude between Detroit (Mich.) and Valley Junction (Wis.) astronomical stations.*

Date, 1873	August 6.	August 8.
	h. m. s.	h. m. s.
Epoch of reference for Dent, (mean)	11 00 00	11 00 00
Mean Δt of clock before signals	− 4 30.741	− 4 37.145
at Detroit local sidereal time	20 42 01.0	20 37 57.
Mean Δt of clock after signals	− 4 30.843	− 4 37.696
at Detroit local sidereal time	23 13 43.5	23 33 38.
Rate of clock from its Δt's	− 00.0400	− 00 1644
Mean Δt of Dent (sidereal) for whole night	+ 8 27 10.871	+ 8 34 57.630
at Valley Junction local sideral time	22 02 55.7	21 32 51.
Coincidences observed at Valley Junction: Dent sidereal	13 08 42.335	13 33 29.887
Clock	22 09 50.000	22 42 31.000
Dent sidereal	13 25 31.674	13 51 44.887
Clock	22 26 39.333	23 00 46.000
Rate of Dent (sidereal) on clock, (by coincidences)	− 00.0214	+ 00.0329
Rate of Dent (sidereal) by clock's Δt's and coincidences	− 00.0614	− 00.1315
Δt_0 of Dent (sidereal) at coincidence	+ 8 27 10.882	+ 8 34 57.358

TABLE 6.—*Combination of results for difference of longitude, &c.*—Continued.

Date, 1873	August 6.	August 8.
	h. m. s.	h. m. s.
True sidereal time of coincidence at Valley Junction	21 52 42.556	22 08 27.449
Δt_0 of clock at same coincidence	— 4 30.808	— 4 37.473
True sidereal time of coincidence at Detroit	22 22 08.525	22 37 53.527
Difference of longitude, by signals, from Detroit to Valley Junction	29 25.969	29 26.078
Means of comparisons from Detroit chronograph.... { Dent sidereal	13 02 10.181	13 19 20.578
{ Clock	22 03 17.998	22 28 21.836
Δt_0 of Dent (sidereal) at comparison	+ 8 27 10.906	+ 8 34 57.583
True sidereal time of comparison at Valley Junction	21 29 21.087	21 54 18.161
Δt_0 of clock at comparison	— 4 30.793	— 4 37.434
True sidereal time of comparison at Detroit	21 58 47.207	22 23 44.402
Difference of longitude, by signals, from Valley Junction to Detroit	29 26.118	29 26.241
Mean difference of longitude, (signals in both directions)	29 26.044	29 26.159

TABLE 7.—*Combination of results for personal equations between Prof. S. W. Robinson and Assist. Engr. O. B. Wheeler.*

Date, 1873	July 5.	July 6.	Sept. 16.	Sept. 18.
	h. m. s.	h. m. s.	h. m. s.	h. m. s.
Epoch of reference for Dent (mean)	10 00 00	9 00 00	7 00 00	7 00 00
Epoch of reference in right ascension	16 51.7	15 55.5	18 35.5	18 43.3
Mean Δt of clock before signals	— 3 11.661	— 3 11.939	— 5 33.357	{Only four stars observed.
Mean right ascension of stars used	19 18	17 39	20 34	
Mean Δt of clock after signals	— 3 11.523	— 3 11.767	— 5 33.235	— 5 33.590
Mean right ascension of stars used	21 52	20 04	22 53	20 58.1*
Rate of clock from these Δt	+ 00.054	+ 00.072	+ 00.053	+ 00.053
Rate of Dent (sidereal) on clocks, by comparisons	— 00.069	— 00.086	— 00.093	— 00.193
Rate of Dent (sidereal) on true sidereal from last two values	— 00.015	— 00.014	— 00.041	— 00.140
Mean Δt of Dent (sidereal) for whole night	+ 6 51 44.140	+ 6 55 28.733	+11 35 32.263	+11 43 19.622
Mean right ascension of all the stars used	20 20	18 18.5	21 11	20 58.1
Interval from epoch to this mean in sidereal time	3 28	2 23	2 35.5	2 14.8
Amount of rate during this interval	— 00.052	— 00.033	— 00.106	— 00.315
Δt of Dent at assumed epoch	+ 6 51 44.192	+ 6 55 28.766	+11 35 32.369	+11 43 19.937
Coincidences of Dent and clock: { Clock	20 51 31.500	19 39 20.949	21 41 57.500	20 42 38.250
{ and Dent (sidereal.)	13 56 36.012	12 40 40.652	10 00 52.381	8 53 45.637
Time of coincidence, (right ascension)	20 48 20.	19 36.2	21 36.5	20 37.1
Interval from epoch to coincidence in sidereal time	3 56.6	3 40.7	3 01.0	1 53.8
Correction for rate of Dent (sidereal) during this interval	— 00.059	— 00.052	— 00.124	— 00.266
Error of Dent (sidereal) at coincidence	+ 6 51 44.133	+ 6 55 28.714	+11 35 32.245	+11 43 19.671
True sidereal time of coincidence by S. W. R	20 48 20.145	19 36 09.366	21 36 24.626	20 37 05.308
Resulting Δt of clock at coincidence, S. W. R	— 3 11.355	— 3 11.583	— 5 32.874	— 5 32.942
Δt of clock at coincidence, O. B. W	— 3 11.580	— 3 11.800	— 5 33.302	— 5 33.609
S. W. R, observes earlier than O. B. W	00.225	00.217	00.428	00.667

*Adopted from rate on September 16. This supposition gives a large change of rate in the Dent chronometer, which is probably due to the short interval of time between the coincidences from which the rate was obtained. This night is given but little weight in the final result.

Latitude.—The observations for latitude were made by both Professor Robinson and Mr. Wright, the instruments being the same, and mounted on the same posts, as in longitude-work at Galena and Valley Junction. The stars were selected from the Catalogue of Mean Declinations of 981 Stars, and arranged in independent pairs.

Tables 8 and 9 give the mean results for each night, the number of independent pairs observed, and the range on each night, together with the final mean, total number of pairs, and entire range in individual results.

TABLE 8.—*General results for latitude of Galena (Ill.) astronomical station.*

Date, 1873.	Mean result for night.	Number of independent pairs.	Range.
	° ′ ″		″
July 14	42 25 10.04	27	6.72
July 17	09.54	32	4.96
July 23	09.04	30	7.58
July 26	09.40	18	5.29
Final mean	42 25 09.50	107	7.58

TABLE 9.—*General results for latitude of Valley Junction (Wis.) astronomical station.*

Date, 1873.	Mean result for night.	Number of independent pairs.	Range.
	° ′ ″		″
August 16	44 03 10.92	23	4.03
August 16	11.06	29	5.83
Final mean	44 03 11.00	52	5.83

Location of the astronomical stations and of the points determined of the land survey.—The co-ordinates of the section corners of the land surveys from the astronomical station were determined either by triangulation from a measured base or by triangulation in connection with measurements along railroad-tracks where it was possible to make very accurate measurements.

The astronomical station at Galena, Ill., was situated as follows:

From Miner's brick house, (east corner,) bearing south 20° 46′ east; distance, 127.9 feet.

From Frazer's brick house, (east corner,) bearing south 76° 08′ east; distance, 164.7 feet.

From Frazer's brick house, (west corner,) bearing south 84° 28′ west; distance, 180.7 feet.

From Frazer's brick house, (southwest corner,) bearing south 25° 41′ west; distance, 194.6 feet.

From Methodist Episcopal church, (northeast corner,) bearing N. 54° 14′ W.; distance, 338.0 feet.

The points of the land survey near Galena determined were the intersection of the fourth principal meridian with the State-line between Illinois and Wisconsin, and the first section-corner of the Wisconsin land survey, on the State line, to the west of the fourth principal meridian.

The co-ordinates of these points from the astronomical stations are respectively in latitude north 9767.89 meters, (or + 5′ 16″.60,) and north 9776.10 meters, (or + 5′ 16″.86;) and in longitude east 420.38 meters, (or — 18″.42,) and west 1190.89 meters, (or + 52″.17.) Then, since the longitude of Detroit, Mich., from Greenwich, is $5^h\ 32^m\ 12^s.24$, (see Lake-Survey Report for 1871 and General Introduction to Washington Observations, United States Naval Observatory for 1871,) we have, for the latitude and longitude of the astronomical station Galena, Ill.—

Latitude = 42° 25′ 09″.50
Longitude = 90° 25′ 52″.05

the intersection of the fourth principal meridian with the State line—

Latitude = 42° 30′ 26″.1
Longitude = 90° 25′ 33″.6

and the first section-corner of the Wisconsin survey on the State line to the west of the fourth principal meridian—

Latitude = 42° 31′ 26″.4
Longitude = 90° 26′ 44″.2

The astronomical station at Valley Junction, Wis., is situated from the intersection of the westerly rails of the Wisconsin Valley Railroad and the West Wisconsin Railroad, as follows:

West = 352.4 feet;
South = 364.0 feet.

The points of the land survey near Valley Junction were the southeast section corner of section 13, and the northeast section-corner of section 1, of township 18 north, range 1 west, being points on the fourth principal meridian.

The co-ordinates of these points from the astronomical station are respectively in latitude—

South 2512.1 meters (or — 1′ 21″.4)

and—

North 2333.5 meters (or + 1′ 15″.6)

and in longitude—

West 1709.6 meters (or + 1′ 16″.7)

and—

West 1724.1 meters (or + 1′ 17″.4)

hence we have for the latitude and longitude of the astronomical station Valley Junction, Wis.—

Latitude = 44° 03′ 11″.00
Longitude = 90° 24′ 39″.30

The southeast section-corner of section 13, township 18 north, range 1 west—

Latitude = 44° 01′ 49″.6
Longitude = 90° 25′ 56″.0

and the northeast section-corner of section 1, of township 18 north, range 1 west—

Latitude = 44° 04′ 26″.6
Longitude = 90° 25′ 56″.7

also points of the land-survey on the correction-line between townships 20 and 21 north, near Valley Junction, as follows, were determined: The southeast and southwest section corners of section 31, township 21 north, range 3 east. The co-ordinates of these points from the astronomical station are respectively—

North 21824.8 meters and east 18492.8 meters;
North 21818.9 meters and east 17091.6 meters;

from which, by a geodetic computation, we find the difference in latitude and longitude between the astronomical station and the points respectively—

Difference in latitude = + 11′ 46″.3; difference in longitude = — 13′ 53″.5
Difference in latitude = + 11′ 46″.2; difference in longitude = — 12′ 50″ 4

hence we have for these points respectively—

Latitude = 44° 14′ 57″.3; longitude = 90° 10′ 45″.8
Latitude = 44° 14′ 57″.2; longitude = 90° 11′ 48″.9

From the southeast corner of the custom-house at St. Paul, Minn., the position of which is, as formerly determined by the lake-survey—

Latitude = 44° 56′ 42″.89
Longitude = 93° 05′ 33″.90

were found the latitude and longitude of the following points in Wisconsin on the correction-line between townships 30 and 31 north: The southeast section corner of section 34, and the southwest section-corner of section 33, of township 31 north, range 19 west. The co-ordinates of the points from the southeast corner of custom house are respectively—

North 19800.0 meters; east 31669.8 meters;
North 19793.0 meters; east 28446.9 meters;

from which, by a geodetic computation, we find the difference in latitude and longitude between the astronomical station and the points respectively—

Difference in latitude = + 10′ 38″.9; difference in longitude = — 21′ 09″.3
Difference in latitude = + 10′ 39″.2; difference in longitude = — 21′ 41″.8

hence we have for these points respectively—

Latitude = 45° 07′ 21″.8; longitude = 92° 41′ 24″.6
Latitude = 45° 07′ 22″.1; longitude = 92° 43′ 52″.1

The local bearings of such portions of lines of the land surveys as were determined were as follows, as found from the differences of the co-ordinates already given:

The State line between Illinois and Wisconsin, from its intersection with the fourth principal meridian, bears west 16′ 17″ north.

The fourth principal meridian from the southeast section corner of section 13, township 18 north, range 1 west, bears north 11′ 10″ west.

The correction line between townships 20 and 21, from the southeast section corner of section 31, township 21 north, range 3 east, bears west 5′ 18″ south; and the correction line between townships 30 and 31, from the southeast section-corner of section 34, bears west 10′ 20″ north.

The computations have been made in duplicate by two computers working independently, chiefly by Subassistants C. H. Kummell, Charles Pratt, T. W. Wright, and J. H. Darling.

Very respectfully, your obedient servant,

O. B. WHEELER,
Assistant Engineer.

General C. B. COMSTOCK,
Superintendent United States Lake-Survey.

APPENDIX C.—DIFFERENCE OF LONGITUDE BETWEEN DETROIT, MICH., AND OGDEN, UTAH.

Report of Mr. O. B. Wheeler, Assistant Engineer.

OFFICE UNITED STATES LAKE-SURVEY,
Detroit, Mich., May 1, 1874.

SIR: I have the honor herewith to report on the instruments employed, the methods of observation and reduction, and the results of a telegraphic connection for difference of longitude between Detroit, Mich., and Ogden, Utah.

In this work, the lake survey co-operated with a party under the direction of Lieut. George M. Wheeler.

The observers in this connection were Dr. F. Kampf, at Ogden, and myself, at Detroit. The transit used at Detroit was the one known as the old Troughton and Simms, the focal length of its object glass being 43.4 inches, and its magnifying power 110 diameters.

The clock (sidereal) and chronograph used were respectively Nos. 184 and 216 Bond & Son.

The position of the transit was the same as given in the lake survey Report for 1871.

The instruments used at Ogden observatory were a combined transit instrument, Würdemann No. 28; a sidereal chronometer, Negus 1491 with break circuit attachment; and a chronograph, with Professor Harkness' (United States Naval Observatory) improvements.

At Ogden, the transit was mounted over the eastern monument in the transit-room.

The method employed was that by transmission of clock signals in connection with arbitrary signals.

The clock signals being automatic, the clock and chronometer were compared by connecting first one and then the other with the telegraph wire, and thus causing them both to record their beats simultaneously, first upon the chronograph at one station, and then upon that at the other.

The clock signals from Ogden were not well recorded on the Detroit chronograph on account of the short breaks in the Ogden chronometer, and the arbitrary signals made approximately every ten seconds were used instead of the automatic signals.

The automatic breaks of the Detroit clock were used, reading every tenth second.

By the use of signals transmitted in both directions, the wave time and loss of time in the use of repeaters become practically eliminated.

The errors and rates of the clock and chronometer and the relative personal equation of the observers being determined, the correct difference of time between the two stations thus becomes known.

In the Detroit observations of time-stars, fifteen wires were observed, but five only were used as constituting a complete observation.

A preliminary reduction, by the method of high and low stars, was first made. The final values, however, depend upon a reduction by the method of least squares. There were five nights on which signals were exchanged.

The collimation on the first three nights was considered constant, and was the mean of the values determined by reversals on slow stars; on the remaining two nights, the collimation entered the equations of condition as an unknown quantity.

The rate was determined from the high and low star reduction, and eliminated from

the equations of condition, except on the first night, when it entered the equations of condition.

On this night, the signals were obtained before any star observations, and the night should have but half weight.

For weighting the equations of condition, the probable error for time-stars taken indiscriminately and observed over a single wire was determined, and found to be $\pm$ 0^s.06.

For the slow stars, the probable error of observing a single wire was computed for each star from all the observations made by me during the year.

The slow stars observed were λ and a *Ursæ Minoris*, 1 *Draconis* (H.), and 226 *Cephei*, and the respective probable errors were found to be $\pm$ 1^s.31, $\pm$ 1^s.03, $\pm$ 0^s.295, and $\pm$ 0^s.213; and since the weight unity was given to the mean of five wires on a time-star, the square roots of the weights for the slow stars over five wires are respectively $\frac{1}{2}\sqrt{2}$, $\frac{1}{2}\sqrt{7}$, $\frac{1}{3}$, $\frac{1}{4}$.

When the number of wires used differed from five, the weights of the resulting times of transit were reduced to this standard number by the formula —

$$W = \frac{n}{5} \cdot \frac{(0.06)^2}{rp}$$

where rp is the probable error of a polar star across a single wire and n the number of wires observed.

The stars selected were either from the American Ephemeris or from the Standard Catalogue of 529 Stars of the German Astronomical Society; none of these stars observed on any of the five nights being rejected.

The collimation adopted for the first three nights was from the mean of three reversals on Polaris, with results as follows:

Sept. 29 ..... = + 0^s.322 for illumination west.
Sept. 30 ..... = + 0^s.206 for illumination west.
Oct. 1 ..... = + 0^s.319 for illumination west.
Adopted mean ..... = + 0^s.282 for illumination west.

The results for clock-corrections and rates on the different nights are as follows:

Detroit clock-correction and rate.

Date.	By clock 184.	Clock-correction.	Hourly rate.
	h. *m.*	*m.* *s.* *s.*	*s.*
September 29, 1873	1 00	−5 37.524 ± 0.034	−0.001
September 30, 1873	22 00	−5 38.309 ± 0.038	−0.020
October 1, 1873	22 00	−5 39.010 ± 0.028	−0.022
October 9, 1873	22 00	−5 42.206 ± 0.026	−0.025
October 10, 1873	23 30	−5 43.500 ± 0.024	−0.085

[1] From letter of Lieut. George M. Wheeler, February 19, 1874, we have—

Corrections and rate of Negus 1491.

Date.	Local sidereal time.	Correction of chronometer.	Hourly rate.	Adopted rate.
	h.	*m.* *s.*	*s.*	*s.*
September 29	20.6	−42 32.174	+0.008	+0.008
September 30	19.7	31.975	+0.008	+0.008
October 1	20.2	31.788	0.000	0.000
October 2	20.4	31.796	−0.005	0.000
October 3	19.9	31.918	−0.009	−0.007
October 4	20.35	32.126	−0.024	−0.017
October 5	19.75	32.691	−0.028	−0.026
October 7	27.2	34.059	−0.013	−0.020
October 8	20.7	34.279	−0.030	−0.022
October 9	20.6	35.003	−0.016	−0.023
October 10	20.6	35.383	−0.046	−0.031
October 11	21.2	36.523		

The comparisons of clock and chronometer, and the resulting differences of longitude, uncorrected for personal equation, are as follows:

Means of direct comparisons of clock and chronometer.

Date.	Detroit chronograph.		Ogden chronograph.	
	Clock 184.	Chronometer 1491.	Clock 184.	Chronometer 1491.
	h. m. s.	h. m. s.	h. m. s.	h. m. s.
September 29	23 58 29.006 = 22	39 36.222	23 53 22.000 = 22	34 29.571
September 30	0 15 25.563 = 22	56 31.561	0 10 42.000 = 22	51 48.342
October 1	23 56 13.239 = 22	37 18.515	23 51 32.000 = 22	32 37.616
October 9	0 18 39.276 = 22	59 44.374	0 30 28.842 = 23	11 34.262
October 10	23 53 31.279 = 22	34 35.494	23 46 02.000 = 22	27 06.572

The above with errors of clock applied.

Date.	Detroit chronograph.		Ogden chronograph.	
	Clock 184.	Chronometer 1491.	Clock 184.	Chronometer 1491.
	h. m. s.	h. m. s.	h. m. s.	h. m. s.
September 29	23 52 51.483 = 21	57 04.059	23 47 44.477 = 21	51 57.407
September 30	0 09 47.209 = 22	13 59.606	0 05 03.647 = 22	09 16.393
October 1	23 50 34.186 = 21	54 46.727	23 45 52.949 = 21	50 05.928
October 9	0 12 57.011 = 22	17 09.332	0 24 46.573 = 22	28 59.216
October 10	23 47 47.656 = 21	52 00.072	23 40 18.387 = 21	44 31.154

Detroit and Ogden—difference of longitude.

Date.	From Ogden record.	From Detroit record.	Mean.	Wave and armature time.
	h. m. s.	h. m. s.	h. m. s.	s.
September 29	1 55 47.070	1 55 47.424	1 55 47.247	0.177
September 30	47.254	47.603	47.428	0.174
October 1	47.121	47.459	47.290	0.169
October 9	47.357	47.679	47.518	0.161
October 10	47.233	47.584	47.409	0.175

Combining the above values for difference of longitude, giving the first result but one-half weight arbitrarily, since the weight of the Ogden time determinations is not given, we have—

$$1^h\ 55^m\ 47^s.393$$

Observations for relative personal equation were made by Dr. Kampf and myself on October 17 and 23 at Detroit.

In these observations, the first observer on any star observed over the first tally of five wires; the second observer observed over the last tally, also of five wires.

The observers became alternately first and second on alternate stars.

The results of fourteen observations on each night are as follows:

Personal equation—Dr. F. Kampf and Assistant Engineer O. B. Wheeler.

Oct. 17, 1873, F. K.—O. B. W. $= -0^s.070 \pm 0^s.0142$
Oct. 23, 1873, F. K.—O. B. W. $= -0^s.153 \pm 0^s.0220$

Combining the twenty-eight results on the supposition that the circumstances of observation were the same on the two nights, we have the following adopted value:

F. K.—O. B. W. $= -0^s.111 \pm 0^s.0139$

Applying this value for personal equation, we have:

Difference of longitude between the east stone pier of the Lake-Survey observatory and the east monument in the transit-room of the Ogden observatory,

$1^h\ 55^m\ 47^s.50$

From Lake-Survey Report 1871, the same Lake-Survey station is given as $24^m00^s.12$ from Washington.

The reductions have been in every case duplicated, and were made chiefly by Assistant Engineers Charles Pratt and Thomas W. Wright.

Very respectfully, your obedient servant,

O. B. WHEELER,
Assistant Engineer.

General C. B. COMSTOCK,
Superintendent U. S. Lake Survey.

Time-determination tables.

In the following tables are contained the abbreviations—

Ill. = Illumination.
C Δi = Reduction to the middle wire.
Aberr. = Aberration, (diurnal.)
A a = Azimuth-correction.
B b = Level-correction.
C c = Collimation-correction.
t' = Observed time of transit of a star; commonly the mean of five wires.
$t = t'$ corrections being made for C Δi, Aber., and B b, and also for C c, and rate when c and ρ do not enter the equations of condition.
a = The right ascension of a star.
$(a-t)$ = (An assumed Δt) = The absolute term of the equations of condition.
a = Deviation from the meridian; + when the instrument points east of south.
c = Distance of the middle wire from the line of collimation; + when illumination is west.
ρ = Hourly rate of clock.
Δt = Clock-corrections; − when fast, + when slow.
θ = An assumed clock-correction at a certain epoch, (clock-time.)
$\delta\theta$ = Difference between the assumed clock-correction and Δt as found; when C Δi is omitted t' = the mean of the several wires reduced to the middle wire.

DETROIT, *September* 29, 1873.

Latitude, 42° 20′ +.—Observer, Assistant Engineer O. B. Wheeler.

Ill.	Star.	C Δi	Aberr.	Rate.	A a	B b	C c	t'	a	Δt
		s.	*s.*	*s.*	*s.*	*s.*	*s.*	*h. m. s.*	*h. m. s.*	*h. m. s.*
W.	12 Ceti	+0.03	−0.02	0.00	+0.13	+ 0.33	+ 0.28	0 29 13.05	0 23 36.24	0 05 37.56
	α Cassiopiæ	+0.06	−0.03	0.00	−0.07	+ 0.85	+ 0.50	38 58.03	33 21.99	37.35
	β Ceti	+0.03	−0.02	0.00	+0.16	+ 0.25	+ 0.30	0 42 52.66	37 15.74	37.64
	ϵ Piscium	+0.03	−0.02	0.00	+0.10	+ 0.40	+ 0.28	1 02 00.76	0 56 23.93	37.62
W.	Polaris	.....	−0.65	0.00	−5.28	+14.19	+13.52	18 19.04	1 13 02.63	
E.	Polaris	.....	−0.65	0.00	−5.28	+15.41	−13.52	18 44.86	13 02.63	
	θ^1 Ceti	−0.03	−0.02	0.00	+0.14	+ 0.34	− 0.29	23 20.52	17 43.31	37.35
	ψ Piscium	−0.03	−0.02	0.00	+0.08	+ 0.48	− 0.29	30 21.40	24 44.04	37.58
E.	o Piscium	−0.03	−0.02	0.00	+0.10	+ 0.44	− 0.29	1 44 21.46	1 38 44.10	37.56

Normal equations.

$$+ 10.98\ a + 0.42\ \rho + 3.40\ \delta\theta - 0.13 = 0$$
$$+ 0.42\ a + 1.43\ \rho + 0.52\ \delta\theta + 0.20 = 0$$
$$+ 3.40\ a + 0.52\ \rho + 7.01\ \delta\theta + 3.08 = 0$$

$a = +0^s.174$ E. of S.
$\rho = -0^s.001$ per hour.
$\delta\theta = -0^s.524$, with the weight 5.85.
$c = +0^s.282$ for illumination west, (adopted from reversals on slow stars.)
θ was assumed $= -5^m\ 37^s$ at 1^h, clock-time.
$\Delta t = -5^m\ 37^s.524 \pm 0^s.034$ at 1^h, clock-time.

NOTE.—On Polaris, eight wires were observed before reversal and five after. Weight was given accordingly in forming the normal equations.

DETROIT, *September* 30, 1873.

Latitude, 42° 20′.—*Observer*, *Assistant Engineer O. B. Wheeler.*

Ill.	Star.	C Δ i	Aberr	Rate.	A a	B b	C c	t′	a	Δt
		s.	s.	s.	s.	s.	s.	h. m. s.	h. m. s.	h. m. s.
W.	ε Delphini	+0.03	−0.02	+0.03	+0.06	+ 0.46	+0.29	20 32 48.30	20 27 10.66	0 05 37.64
	γ² Delphini	+0.03	−0.02	+0.03	+0.06	+ 0.49	+0.29	46 25.60	40 47.84	37.84
	μ Aquarii	+0.03	−0.02	+0.03	+0.10	+ 0.33	+0.29	51 28.01	45 50.43	37.58
	32 Vulpeculæ	+0.04	−0.02	+0.03	+0.04	+ 0.58	+0.32	20 54 48.32	20 49 10.72	37.60
W.	ζ Cygni	+0.04	−0.02	+0.02	+0.03	+ 0.60	+0.32	21 13 11.38	21 07 33.83	37.55
E.	1 Draconis (L. C.)	+0.62	+0.11	+0.01	+0.70	− 2.21	+2.00	24 26.02	18 48.93	
	β Aquarii	−0.03	−0.02	+0.01	+0.09	+ 0.38	−0.28	30 32.78	24 54.78	38.00
	Aquarii	.....	−0.02	+0.01	+0.09	+ 0.36	−0.29	36 40.02	31 01.87	38.15
	ε Pegasi	−0.03	−0.02	+0.01	+0.07	+ 0.48	−0.29	43 37.31	37 59.23	38.08
	μ Capricorni	−0.03	−0.02	+0.01	+0.10	+ 0.32	−0.29	21 52 02.88	21 46 24.89	38.00
	θ Pegasi	−0.03	−0.02	.....	+0.07	+ 0.45	−0.28	22 09 28.04	22 03 50.05	38.00
	θ Aquarii	−0.03	−0.02	.....	+0.09	+ 0.35	−0.29	15 48.63	10 10.50	38.13
	γ Aquarii	−0.03	−0.02	−0.01	+0.08	+ 0.39	−0.28	20 46.37	15 08.30	38.07
	π Aquarii	−0.03	−0.02	−0.01	+0.08	+ 0.40	−0.28	24 28.03	18 49.98	38.05
	226 Cephei	−0.35	−0.06	−0.01	−0.26	+ 1.78	−1.13	35 43.33	30 05.36	
	ζ Pegasi	−0.03	−0.02	−0.01	+0.07	+ 0.46	−0.29	40 48.38	35 10.14	38.24
	λ Aquarii	−0.03	−0.02	−0.02	+0.59	+ 0.34	−0.29	22 51 40.13	22 46 01.94	38.19
	β Ceti	−0.03	−0.02	−0.06	+0.11	+ 0.18	−0.30	0 42 53.89	0 37 15.74	38.15
	ε Piscium	−0.03	−0.02	−0.07	+0.07	+ 0.28	−0.28	1 02 02.26	0 56 23.94	38.32
E.	Polaris	.....	−0.65	−0.07	−3.61	+ 9.77	−8.63	18 47.59	1 13 02.80	
W.	Polaris	.....	−0.65	−0.07	−3.61	+14.42	+8.63	18 25.69	13 02.80	
	θ¹ Ceti	+0.03	−0.02	−0.07	+0.09	+ 0.32	+0.29	23 21.00	17 43.32	37.68
W.	η Piscium	+0.03	−0.02	−0.07	+0.06	+ 0.46	+0.29	1 30 21.87	1 24 44.04	37.83

Normal equations.

$$+ 20.56\,a + 10.66\,\delta\theta + 0.85 = 0$$
$$+ 10.66\,a + 19.37\,\delta\theta + 4.72 = 0$$

$a = +\ 0^s.119$ E. of S.
$\delta\theta = -\ 0^s.309$, with the weight 13.84.
$c = +\ 0^s.282$ for illumination west, (adopted from reversals on slow stars.)
$\rho = -\ 0^s.020$ per hour, (adopted from high and low star reduction.)
Assumed value of $\theta = -\ 5^m\ 38^s$ at 22^h, clock-time.
$\Delta t = -\ 5^m\ 38^s.309 \pm 0^s.038$ at 22^h, clock-time.

NOTE.—On 1 Draconis fifteen wires were observed: on 226 Cephei also fifteen wires: on Polaris, eight before reversal and four after. Weight was given accordingly in forming the normal equations.

DETROIT, *October* 1, 1873.

Latitude, 42° 20′.—*Observer*, *Assistant Engineer O. B. Wheeler.*

Ill.	Star.	C Δ i	Aberr	Rate.	A a	B b	C c	t′	a	Δt
		s.	s.	s.	s.	s.	s.	h. m. s.	h. m. s.	h. m. s.
E.	θ Aquilæ	− 0.03	−0.02	+0.04	+0.22	+ 0.23	− 0.28	20 10 25.63	20 04 47.06	0 05 38.73
	α² Capricorni	− 0.03	−0.02	+0.04	+0.26	+ 0.20	− 0.29	16 41.14	11 02.58	38.72
	π Capricorni	− 0.03	−0.02	+0.04	+0.29	+ 0.19	− 0.30	25 43.89	20 05.34	38.72
	ε Delphini	− 0.03	−0.02	+0.03	+0.17	+ 0.35	− 0.29	32 49.39	27 10.64	38.86
	γ² Delphini	− 0.03	−0.02	+0.03	+0.15	+ 0.40	− 0.29	46 26.69	40 47.81	38.12
	μ Aquarii	− 0.03	−0.02	+0.03	+0.25	+ 0.29	− 0.29	51 29.05	45 50.42	38.86
	32 Vulpeculæ	− 0.04	−0.02	+0.02	+0.09	+ 0.51	− 0.32	20 54 49.69	20 49 10.71	38.22
E.	ζ Cygni	− 0.04	−0.02	+0.02	+0.08	+ 0.61	− 0.32	21 13 12.77	21 07 33.82	38.22
W.	1 Pegasi	+ 0.03	−0.02	+0.01	+0.13	+ 0.51	+ 0.30	21 53.01	16 14.96	38.01
	β Aquarii	+ 0.03	−0.02	+0.01	+0.24	+ 0.35	+ 0.28	30 32.89	24 54.77	38.01
	ξ Aquarii	+ 0.03	−0.02	+0.01	+0.25	+ 0.33	+ 0.29	36 39.94	31 01.86	38.97
	ε Pegasi	+ 0.03	−0.02	+0.01	+0.17	+ 0.44	+ 0.29	43 37.16	37 59.22	38.86
	μ Capricorni	+ 0.03	−0.02	0.00	+0.27	+ 0.30	+ 0.29	21 52 03.08	21 46 24.84	38.07
	20 Pegasi	+ 0.03	−0.02	0.00	+0.16	+ 0.45	+ 0.29	22 00 34.72	54 56.49	38.14
	α Aquarii	+ 0.03	−0.02	0.00	+0.21	+ 0.37	+ 0.28	05 56.23	21 59 18.10	38.00
	θ Pegasi	+ 0.03	−0.02	0.00	+0.19	+ 0.41	+ 0.28	09 28.24	22 03 50.05	38.06
	θ Aquarii	+ 0.03	−0.02	−0.01	+0.25	+ 0.32	+ 0.29	15 48 59	10 10.49	38.96
	γ Aquarii	+ 0.03	−0.02	−0.01	+0.22	+ 0.36	+ 0.28	20 46.52	15 08.29	38.09
	π Aquarii	+ 0.03	−0.02	−0.01	+0.21	+ 0.37	+ 0.28	24 28.14	18 49.97	38.03
	226 Cephei	−47.94	−0.06	−0.01	−0.69	+ 1.68	+ 1.13	36 29.53	30 05.32	
	ζ Pegasi	+ 0.03	−0.02	−0.01	+0.17	+ 0.44	+ 0.29	40 48.36	35 10.13	38.13
	λ Pegasi	+ 0.03	−0.02	−0.02	+0.11	+ 0.53	+ 0.30	46 05.56	40 27.31	38.19
	λ Aquarii	.....	−0.02	−0.02	+0.25	+ 0.34	+ 0.29	22 51 40.14	46 01.94	38.04
	α Pegasi	.....	−0.02	−0.02	+0.15	+ 0.49	+ 0.29	23 04 06.78	22 58 28.67	38.00
	α Andromedæ	+ 0.04	−0.02	−0.02	+0.09	+ 0.49	+ 0.32	0 07 30.50	0 01 52.24	38.16
	β Ceti	+ 0.03	−0.02	−0.04	+0.29	+ 0.21	+ 0.30	42 53.96	37 15.75	38.08
W.	ε Piscium	+ 0.03	−0.02	−0.04	+0.18	+ 0.32	+ 0.29	1 02 02.15	0 56 23.94	38.97
	Polaris	.....	−0.65	−0.05	−9.53	+11.13	+13.34	18 26.22	1 13 02.99	
E.	Polaris	.....	−0.65	−0.05	−9.53	+12.47	−13.34	18 51.56		
	θ¹ Ceti	− 0.03	−0.02	−0.05	+0.25	+ 0.28	− 0.29	23 22.01	17 43.34	38.21
E.	η Piscium	− 0.03	−0.02	−0.06	+0.15	+ 0.39	− 0.29	1 30 22.90	1 24 44.04	38.00

Normal equations.

$$+18.78\,a + 16.69\,\delta\theta - 5.73 = 0$$
$$+16.69\,a + 27.71\,\delta\theta - 4.96 = 0$$

$a = +0^s.314$ E. of S.
$\delta\theta = -0^s.010$, with the weight 12.88.
$c = +0^s.282$ for illumination west, (adopted from reversals on slow stars.)
$\rho = -0^s.022$ per hour, (adopted from high and low star reduction.)
Assumed value of $\theta = -5^m\,39^s$ at 22^h, clock-time.
$\Delta t = -5^m\,39^s.010 \pm 0^s.028$, at 22^h, clock-time.

NOTE.—On 226 Cephei the first tally of five wires was observed, and on Polaris eight wires before and four after reversal, and on λ Aquarii and α Pegasi four wires each were observed. Weight was given accordingly in forming the normal equations.

DETROIT, *October* 9, 1873.

Latitude, 42° 20′.—*Observer, Assistant Engineer O. B. Wheeler.*

Ill.	Star.	C Δ i	Aberr	Rate.	A a.	B b.	C c.	t′	a	Δ t
		s.	s.	s.	s.	s.	s.	h. m. s.	h. m. s.	h. m. s.
E.	α^2 Capricorni	−0.03	−0.02	+0.04	+0.22	−0.03	− 0.32	20 16 20.47	20 10 38.60	0 05 41.73
	ε Delphini	−0.03	−0.02	+0.04	+0.14	+0.03	− 0.32	32 52.68	27 10.52	42.00
	α Cygni	.....	−0.02	+0.03	−0.01	+0.06	− 0.44	42 50.27	37 07.55	42.34
	μ Aquarii	−0.03	−0.02	+0.03	+0.21	+0.03	− 0.32	51 32.38	45 50.31	41.97
	ν Cygni	−0.04	−0.02	+0.03	+0.01	+0.09	− 0.41	20 58 10.63	20 52 27.89	42.40
	61^1 Cygni	.....	−0.02	+0.02	+0.02	+0.10	− 0.39	21 06 56.90	21 01 14.30	42.33
E.	1 Draconis (L. C.)	.....	+0.11	+0.01	+1.55	−0.37	+ 2.19	24 28.91	18 50.26	.....
W	1 Draconis (L. C.)	.....	+0.11	+0.01	+1.55	+0.25	− 2.19	24 34.46	18 50.26	.....
	ξ Aquarii	+0.03	−0.02	+0.01	+0.21	−0.02	+ 0.32	36 43.40	31 01.78	42.15
	ε Pegasi	+0.03	−0.02	+0.01	+0.15	−0.03	+ 0.32	43 40.86	37 59.13	42.19
	μ Capricorni	+0.03	−0.02	0.00	+0.23	−0.02	+ 0.32	21 52 06.46	46 24.80	42.20
	α Aquarii	+0.03	−0.02	0.00	+0.18	−0.01	+ 0.30	22 04 59.80	21 59 18.03	42.25
	θ Aquarii	+0.03	−0.02	−0.01	+0.21	−0.01	+ 0.32	15 52.01	22 10 10.42	42.11
	γ Aquarii	+0.03	−0.02	−0.01	+0.18	0.00	+ 0.31	20 49.99	15 08.24	42.24
	π Aquarii	+0.03	−0.02	−0.01	+0.18	+0.01	+ 0.31	24 31.61	18 49.91	42.20
	η Aquarii	+0.03	−0.02	−0.01	+0.18	+0.01	+ 0.31	34 33.82	28 52.30	42.02
	226 Cephei	.....	−0.06	−0.01	−0.58	+0.08	+ 1.24	35 46.15	30 04.93	.....
	λ Pegasi	.....	−0.02	−0.02	+0.09	+0.04	+ 0.33	46 09.13	40 27.26	42.29
	λ Aquarii	+0.03	−0.02	−0.02	+0.21	+0.03	+ 0.32	22 51 43.59	46 01.90	42.24
	α Pegasi	+0.03	−0.02	+0.03	−0.13	+0.05	+ 0.32	23 04 10.38	22 58 28.64	42.22
	θ Piscium	+0.03	−0.02	−0.04	+0.16	+0.05	+ 0.31	28 15.97	23 21 34.17	42.29
	ι Piscium	+0.03	−0.02	−0.04	+0.16	+0.06	+ 0.31	39 09.63	33 27.85	42.28
	ω Piscium	.....	−0.02	−0.05	+0.16	+0.07	+ 0.31	23 58 31.94	23 52 50.16	42.25
	α Andromedæ	+0.04	−0.02	−0.05	+0.07	+0.11	+ 0.35	0 07 34.17	0 01 52.26	42.41
	ε Piscium	+0.03	−0.02	−0.08	+0.15	+0.12	+ 0.32	1 02 05.88	0 56 24.00	42.40
W.	Polaris	.....	−0.65	−0.08	−8.04	+0.55	+12.98	18 41.43	1 13 04.18	.....
E.	Polaris	.....	−0.65	−0.08	−8.04	+4.84	−12.98	18 02.87	04.98	.....
	θ^1 Ceti	−0.03	−0.02	−0.08	+0.21	+0.11	− 0.32	23 25.63	17 43.41	42.09
	η Piscium	−0.03	−0.02	−0.09	+0.13	+0.15	− 0.32	30 26.62	24 44.16	42.28
	o Piscium	−0.03	−0.02	−0.09	+0.15	+0.14	− 0.32	1 44 26.60	1 38 44.22	42.21
	α Arietis	−0.03	−0.02	−0.10	+0.09	+0.09	− 0.33	2 05 46.65	2 00 03.96	42.39
E.	ξ^1 Ceti	−0.03	−0.02	−0.11	+0.15	0.00	− 0.32	2 12 01.48	2 06 18.98	42.17

Normal equations.

$$+21.56\,a + 2.66\,c + 14.67\,\delta\theta - 3.51 = 0$$
$$+2.66\,a + 51.34\,c + 4.75\,\delta\theta - 15.58 = 0$$
$$+14.67\,a + 4.75\,c + 26.26\,\delta\theta + 0.06 = 0$$

$a = +0^s.265$ E. of S.
$c = +0^s.309$ for illumination west.
$\delta\theta = -0^s.206$, with the weight 16.11.
$\rho = -0^s.025$ per hour, (adopted from high and low star reduction.)
Assumed value of $\theta = -5^m\,42^s$ at 22^h, clock-time.
$\Delta t = -5^m\,42^s.206 \pm 0^s.026$ at 22^h, clock-time.

NOTE.—On α Cygni, 61^1 Cygni, ω Piscium, four wires were observed; on λ Aquarii, three; on 1 Draconis, seven before and five after reversal; on Polaris, eight before and five after reversal. Weight was given accordingly in forming the normal equations.

DETROIT, *October* 10, 1873.

Latitude, 42° 20′.—*Observer, Assistant Engineer O. B. Wheeler.*

Ill.	Star.	C Δ i	Aberr	Rate.	A a	B b	C c	t′	a	Δt
		s.	s.	s.	s.	s.	s.	h. m. s.	h. m. s.	h. m. s.
E	λ Ursæ Minoris	.....	−0. 83	+0. 30	−3. 93	−3. 40	−7. 61	19 56 36. 96	19 50 46. 36	
W.	λ Ursæ Minoris	.....	−0. 83	+0. 30	−3. 93	−1. 97	+7. 61	19 56 27. 88	19 50 46. 36	
	a^2 Capricorni	+0. 03	−0. 02	+0. 28	+0. 09	0. 00	+0. 15	20 16 45. 45	20 11 02. 44	0 05 [illegible]
	π Capricorni	+0. 03	−0. 02	+0. 26	+0. 09	+0. 02	+0. 15	25 48. 01	20 05. 20	[illegible]
	ε Delphini	+0. 03	−0. 02	+0. 26	+0. 05	+0. 07	+0. 15	32 53. 60	27 10. 50	[illegible]
	α Cygni	+0. 05	−0. 02	+0. 23	−0. 01	+0. 17	+0. 20	42 50. 55	37 07. 55	[illegible]
	μ Aquarii	+0. 03	−0. 02	+0. 23	+0. 08	+0. 10	+0. 15	20 51 33. 35	20 45 50. 30	[illegible]
	61^1 Cygni	+0. 04	−0. 02	+0. 20	+0. 01	+0. 15	+0. 18	21 06 57. 42	21 01 14. 28	[illegible]
	ζ Cygni	+0. 04	−0. 02	+0. 19	+0. 03	+0. 08	+0. 16	13 16. 81	07 33. 67	[illegible]
W.	1 Draconis (L. C.)	.....	+0. 11	+0. 18	+0. 59	−0. 12	−1. 01	24 34. 25	18 50 42	
E.	1 Draconis (L. C.)	.....	+0. 11	+0. 18	+0. 59	−0. 44	+1. 01	24 30. 94	18 50. 42	
	β Aquarii	.....	−0. 02	+0. 17	+0. 08	+0. 07	−0. 14	30 38. 09	24 54. 66	[illegible]
	ξ Aquarii	.....	−0. 02	+0. 16	+0. 09	+0. 07	−0. 14	36 45. 25	31 01. 76	[illegible]
	ε Pegasi	−0. 03	−0. 02	+0. 15	+0. 06	+0. 09	−0. 15	43 42. 60	37 59. 11	[illegible]
	μ Capricorni	−0. 03	−0. 02	+0. 14	+0. 09	+0. 06	−0. 15	21 52 08. 26	46 24. 79	[illegible]
	α Aquarii	−0. 03	−0. 02	+0. 12	+0. 07	+0. 09	−0. 14	22 05 01. 54	21 59 18. 02	[illegible]
	η Aquarii	−0. 03	−0. 02	+0. 08	+0. 07	+0. 11	−0. 14	34 35. 81	22 28 52. 30	[illegible]
	λ Aquarii	−0. 03	−0. 02	+0. 06	+0. 08	+0. 10	−0. 15	51 45. 42	46 01. 89	[illegible]
	α Pegasi	−0. 03	−0. 02	+0. 04	+0. 05	+0. 16	−0. 15	23 04 12. 32	22 58 28. 63	[illegible]
	α Andromedæ	−0. 04	−0. 02	−0. 05	+0. 03	+0. 14	−0. 16	0 07 36. 25	0 01 52. 26	[illegible]
	β Ceti	−0. 03	−0. 02	−0. 10	+0. 09	+0. 05	−0. 15	42 59. 46	37 15. 79	[illegible]
	ε Piscium	.....	−0. 02	−0. 13	+0. 06	+0. 07	−0. 14	1 02 07. 69	0 56 24. 01	[illegible]
E.	Polaris	.....	−0. 65	−0. 15	−3. 07	+2. 02	−5. 96	18 57. 08	1 13 04. 38	
W.	Polaris	.....	−0. 65	−0. 15	−3. 07	+3. 90	+5. 96	18 43. 58	1 13 04. 38	
	θ^1 Ceti	.....	−0. 02	−0. 16	+6. 09	+0. 08	+0. 14	23 26. 66	17 43. 42	[illegible]
	η Piscium	+0. 03	−0. 02	−0. 17	+0. 05	+0. 12	+0. 15	30 27. 60	24 44. 17	[illegible]
	β Arietis	+0. 03	−0. 02	−0. 20	+0. 04	+0. 17	+0. 15	1 53 23. 89	1 47 40. 52	[illegible]
	α Arietis	+0. 03	−0. 02	−0. 21	+0. 04	+0. 21	+0. 15	2 05 47. 35	2 00 03. 97	[illegible]
W.	ξ′ Ceti	+0. 03	−0. 02	−0. 23	+0. 06	+0. 23	+0. 15	2 12 02. 44	2 06 18. 99	[illegible]

Normal equations.

$$26.39\,a + 0.93\,c + 12.87\,\delta\theta + 4.81 = 0$$
$$0.93\,a + 57.49\,c + 1.92\,\delta\theta - 7.11 = 0$$
$$12.87\,a + 1.92\,c + 22.34\,\delta\theta + 11.61 = 0$$

$a = +0^s.101$ E. of S.
$c = +0^s.142$ for illumination west.
$\rho = -0^s.590$ with the weight 16.03.
$\rho = -0.085$ per hour (adopted from high and low star reduction.)
θ was assumed $= -5^m\,43^s$ at $23^h\,30^m$ clock-time.
$\Delta t = -5^m\,43^s.590 \pm 0^s.024$ at $23^h\,30^m$ clock-time.

NOTE.—On β Aquarii and ξ Aquarii, ε Piscium and θ^1 Ceti four wires were observed on γ Ursæ Minoris, seven before and seven after reversal; on 1 Draconis, seven before and four after reversal; on Polaris, eight before and four after reversal. Weight was given accordingly in forming the normal equations.

APPENDIX D.—RESULTS OF MAGNETIC OBSERVATIONS.

Report of Capt. A. N. Lee, Corps of Engineers.

OFFICE U. S. LAKE-SURVEY,
Detroit, Mich., October 21, 1873.

MAJOR: I have the honor to submit herewith the results of magnetic observations made under your instructions during the months of July and August, 1873.

The report of observations made in May and June of this year has been already submitted to you.

Your letter of instruction of July 8, 1873, directed me "to proceed to the following places in the order named," and from the last to return to Detroit; viz: Forestville, Mich.; Fort Gratiot, Mich.; Marquette, Mich.; Copper Harbor, Mich.; Du Luth and St. Paul, in Minn.; Milwaukee, Wis.; Michigan City, Ind.; and Grand Haven, Mich.

At each place I was to observe for declination, horizontal intensity and dip, and wherever it was practicable, use the same points as occupied by Lieutenant Smith, Topographical Engineers, in 1858 and 1859.

During the time that has elapsed since Lieutenant Smith's observations so many

changes have occurred at the different stations, especially those in towns or their vicinities, that in several cases I found it impossible to use his old points.

In others I found the points used by him had been evidently selected without reference to future occupation, and where such was the case I thought it advisable to choose others.

At Fort Gratiot the land in the vicinity of the old station has passed into the hands of the Grand Trunk Railroad. The buildings they have erected prevented me from occupying the exact spot used by Lieutenant Smith. I selected a station, however, as near the old one as possible, and on the Government reservation.

At Marquette, Milwaukee, and Grand Haven I was also obliged to occupy new points.

The instruments used were a Würdemann theodolite magnetometer No. 3, Barrow dip-circle No. 26, and a Würdemann theodolite, No. 85, 8-inch limb, reading to 10″.

For time I used a Kühlberg chronometer-watch, running to mean time, with a rate of about 2ˢ gaining. The collimating-magnets used were marked at ends C 2 and C 3. C 2 is 3.75 inches in length and 0.79 inch in diameter. C 3 is 2.41 inches in length and 0.79 inch in diameter.

Before going into the field in 1872, the zeros of the magnet-scales were accurately determined, as were also the values of one division of each scale.

The zeros were redetermined before commencing work, in 1873.

The moment of inertia of magnet C 2 and stirrup were also determined before leaving Detroit in 1872.

Additional observations were made on my return from the field in 1872, for the more accurate determination of this constant. The logarithm of adopted value is log K = 1.1548012. Since my return from the field this fall I have made several sets of observations, to determine whether this constant has changed. The result of these observations is log K = 1.1501082. The inertia-ring used being too light for the magnets, this discrepancy in the two values for K does not prove that the moment of inertia has changed.

The old value, being the mean of 13 or 14 sets of careful observations, is retained and used in the computation.

I also determined, in the spring of 1873, the value for "P" for the pair of magnets used. This value being practically zero, it has not been taken into account in the computations.

The weight of the magnets used rendered it necessary to suspend them by *six* threads; this being the smallest number that could be used without danger of constant breakage.

The torsion was removed before observing by suspending the brass cylinder of same weight as the heavy magnet, and allowing it to remain for several hours, and whenever practicable over night.

The observations for declination were made to include the early morning eastern elongation, and continued at intervals during the day, to an hour in the afternoon sufficiently late to include the western elongation.

The mean declination for the day, obtained by taking the mean of the elongations, is the one given.

In the observations for dip both needles were used, care being taken to reverse the poles of the needles, using always the same number of strokes of the bar-magnets. As far as practicable, a third set was taken on a succeeding day as a check against large errors.

Careful observations have been made to determine the instrumental correction for the dip-circle used; but as this correction is less than the probable error, it has not been applied.

The observations were made under an astronomical tent, care being taken to remove all iron from the poles; and nothing was carried about the person or allowed to be brought near the tent that could in any way affect the magnets.

Two sets of observations for azimuth were made at each station, (except two,) one of which at least was at an elongation.

I am, major, very respectfully, your obedient servant,

A. N. LEE,
Captain of Engineers, U. S. A.

Maj. C. B. COMSTOCK,
Corps of Engineers, U. S. A.

NOTE.—In submitting the results of my magnetic observations for 1872, I omitted to give the declination at Charlotte, N. Y.; the results appearing to me too small to be anywhere near correct, viz, 3° 44′ 26″ W.

I observed again at Charlotte this year, at a different point, and on two days. I found the mean for the two days to be 3° 46′ 09″ W.

These results show, I think, that the error is due to local attraction, and not to the observations.

Observations for dip, 1873.

Stations.	Date.	No. of needle.	Poles direct.	Poles reversed.	Mean.	Dip.
	1873.		° ′	° ′	° ′	° ′
Forestville	July 11	I	74 54	74 52	74 53	
	July 11	II	74 53	75 00	74 56	74 54
	July 12	II	74 53	74 52	74 53	
Fort Gratiot	July 15	I	74 19	74 22	74 20	
	July 15	II	74 21	74 27	74 24	74 22
	July 16	I	74 23	74 26	74 24	
Fort Brady	July 22	I	77 29	77 32	77 30	
	July 22	II	77 31	77 33	77 32	77 30
	July 23	II	77 28	77 32	77 30	
Marquette	July 29	I	75 51	75 49	75 50	75 48
	July 29	II	75 48	75 45	75 46	
Copper Harbor	Aug. 2	I	78 05	78 04	78 04	
	Aug. 3	II	78 01	78 02	78 02	78 02
	Aug. 3	I	78 00	78 02	78 01	
Du luth	Aug. 13	II	76 20	76 16	76 18	
	Aug. 13	I	76 14	76 16	76 15	76 17
	Aug. 14	II	76 18	76 21	76 19	
Saint Paul	Aug. 19	I	74 55	74 51	74 53	
	Aug. 19	II	74 58	74 54	74 56	74 55
	Aug. 20	II	74 58	74 59	74 58	
Milwaukee	Aug. 22	I	73 43	73 42	73 43	
	Aug. 22	II	73 45	73 42	73 43	73 43
Michigan City	Aug. 25	I	72 43	72 41	72 42	
	Aug. 25	II	72 44	72 46	72 45	
	Aug. 26	II	72 50	72 36	72 43	72 43
Grand Haven	Aug. 28	I	73 56	73 54	73 55	
	Aug. 28	II	73 56	74 07	74 01	
	Aug. 29	I	73 59	73 57	73 58	73 58

Final results, 1873.

Stations.	Date.	Latitude.	Longitude.	Declination.	Dip.	Horizontal intensity.		Total intensity.	M.	Remarks.
		° ′ ″	° ′ ″	° ′ ″	° ′		ft.			
Forestville	July 11	43 39 36	82 34 15	July 12 1 32 56 W.	74 54	3.636	R = 1	.....	0.6267	Azimuth of mark by observations at elongation, 11° 00′ 51″; by other observations, 11° 00′ 47″.—Station, 100 feet east of astronomical post; soil, clay
						3.631	1.33	.....	0.6277	
	July 12	43 39 36	82 34 15	July 13 1 28 30 W.	.....	3.642	1.0	13.957	0.6268	
						3.716	1.0	.....	0.6256	
Fort Gratiot...	July 15	42 59 52	82 25 00	0 37 32 W.	.....	3.713	1.33	.....	0.6261	Azimuth of mark by observations at elongation, 86° 32′ 45″; by other observations, 86° 32′ 42″.—Station, 200 feet west of south end of old bake-house; soil, sandy.
	July 16	42 59 52	82 25 00	0 36 31 W.	74 22	3.719	1.0	13.790	0.6271	
Fort Brady	July 22	46 30 07	84 20	0 04 31 W.	.....	3.041	1.0	.....	0.6253	Azimuth of mark by observations at elongation, July 21, 95° 34′ 55″; July 23, 95° 35′ 17″.—Station, 273 feet northwest of flag-staff; soil, sand.
						3.046	1.0	.....	0.6263	
	July 23	46 30 07	84 20	0 05 19 W.	77 30	3.046	1.33	14.064	0.6264	
Marquette.....	July 26	46 32 40	87 33 30	July 29 4 40 24 E.	.....	3.441	1.0	.....	0.6279	One observation for azimuth at elongation.—Station, on beach, 800 feet northwest of light-house; soil, sand.
						3.425	1.33	.....	0.6274	
	July 28	46 32 40	87 33 30	4 20 57 E.	75 48	3.432	1.0	13.991	0.6261	
Copper Harbor.	Aug. 1	47 28 30	88 02 00	Aug. 3 4 04 23 E.	.....	2.923	1.0	.....	0.6274	Azimuth of mark by observations at elongation, 92° 32′ 50″; by other observations, 92° 32′ 56″.—Station, 100 feet north of flag-staff; soil, rocky.
						2.932	1.0	.....	0.6285	
	Aug. 2	47 28 30	88 02 00	4 02 17 E.	78 02	2.928	1.33	14.116	0.6295	
Duluth	Aug. 12	46 45 27	92 04 31	Aug. 13 11 57 33 E.	.....	3.391	1.0	.....	0.6255	Azimuth of mark by observations at elongation, 19° 06′ 55″; by other observations, 19° 06′ 49″.—Station, on Minnesota Point, 540 feet southeast of Mr. Peck's house; soil, sand.
						3.397	1.0	.....	0.6257	
	Aug 15	46 45 27	92 04 31	11 47 04 E.	76 17	3.397	1.33	14.318	0.6256	
St. Paul.....	Aug. 18	44 56 43	93 05 24	Aug. 20 10 55 30 E.	.....	3.646	1.0	.....	0.6241	Azimuth-observations on two nights at elongation, but different marks used, so that the results cannot be compared.—Station, 50 feet west of south front of county court-house; soil, rocky.
						3.651	1.0	.....	0.6239	
	Aug. 19	44 56 43	93 05 24	10 55 59 E.	74 55	3.647	1.33	14.018	0.6247	
Milwaukee	Aug. 23	43 02 51	87 55 05	6 22 23 E.	.....	3.897	1.0	.....	0.6269	Azimuth-observations at elongation of Polaris.—Station, south side of Spring street, between Fourth and Fifth; soil, sand and clay.
	Aug. 22	43 02 51	87 55 05	6 22 23 E.	73 43	3.897	1.33	13.900	0.6270	
Michigan City.	Aug. 25	41 50 42	87 06 45	3 58 23 E.	.....	4.097	1.0	.....	0.6253	Azimuth of mark at elongation, 90° 45′ 43″; by other observations, 90° 45′ 49″.—Station, on beach, 300 feet north of light-house; soil, sand.
						4.087	1.0	13.770	0.6263	
	Aug. 26	41 50 42	87 06 45	3 59 41 E.	72 43	4.089	1.33	.....	0.6259	
Grand Haven..	Aug. 27	43 05 00	86 12 33	Aug. 29 3 27 40 E.	.....	3.854	1.0	.....	0.6250	Two sets of azimuth-observations, but at different marks, so that they cannot be compared.—Station, in lot in rear of jail, near center of lot; soil, sand.
						3.848	1.0	.....	0.6241	
	Aug. 28	43 05 00	86 12 33	3 28 43 E.	73 58	3.848	1.33	13.940	0.6238	
Charlotte, N.Y.	(1872)	.....	.....	3 44 26 W.	.....	.....	.....	.....	.....	

APPENDIX E.—REMEASUREMENT OF THE KEWEENAW BASE.

Report of Major C. B. Comstock, Corps of Engineers.

1. This base was originally measured in 1867, but as General W. F. Raynolds, at that time in charge of the Lake-Survey, had little confidence in the precision of the work, on account of the muddy condition of the ground during the measurement giving instability to the measuring-tubes, it was decided to remeasure it. This was done in the summer and fall of 1873 by Assistant Engineer E. S. Wheeler, aided by Assistant Engineers C. F. Burton and C. Pratt.

The base-apparatus used is a compensating one by Würdemann, a copy of that of the Coast Survey, and is described in the Lake-Survey Report for 1868, the original being described in the Coast-Survey Report for 1854. The measuring part consists of tubes 1 and 2, each about 15 feet long.

In previous bases of the Lake-Survey, the measurement had been made without tents over the tubes; in this, Assistant Engineer Wheeler was directed to make the measurement under movable tents, so as to avoid at least in part the large daily fluctuations in the length of the base-tubes, arising from unequal temperatures of the compensating bars, the upper being most heated by the sun. This fluctuation amounts in extreme cases to 0.00500 inch, the length of a tube being approximately 15 feet.

A mercurial thermometer can only be depended on to give the temperature of a standard bar when the temperature of the bar varies very slowly. For this reason, at previous bases, the length of the tubes had been deduced from comparisons with the standard bar at its maximum or minimum daily length, as then only could its temperature be closely determined by thermometers. The mean of these maxima and minima results was taken as the working length of the tube during measurement for the Fond du Lac base.

But as this result might not be precisely the mean length of a tube during the time of actual measurement, it was decided to attempt to determine the length of the tube under circumstances as nearly the same as those of measurement as possible. Accordingly, Assistant Engineer Wheeler was directed to make the comparisons under tents (as the measurement was to be so made) instead of in a house as heretofore, and to continue them through the part of the day in which measuring was done, (from 8 a. m. to 6 p. m.,) in the expectation that the daily mean of such comparisons would give closely the mean length of the tube during measurement on a similar day.

As the thermometers could not be trusted to give the rapidly-varying temperature of the standard bar, that temperature was fixed by packing the bar in ice kept constantly renewed. To avoid its cooling effect on the tube it was only introduced between the comparators once in two hours, the stability of the very steady stone posts on which the comparators stood being trusted in the interval.

As the length of the tubes at the Fond du Lac base had been determined by maxima and minima comparisons under cover while the tubes during measurement had been exposed to the sun, Assistant Engineer Wheeler was also directed to ascertain the differences between the mean lengths of the two tubes as resulting from maxima and minima comparisons under cover, and as resulting from comparisons continued through the working-day, the tubes having no tents over them to protect them from the sun or sky.

These differences are corrections to be applied to the lengths of the tubes resulting from maxima and minima comparisons used in reducing the Fond du Lac base.

2. Keweenaw base is approximately parallel to the west shore of Keweenaw Bay, its north end being about 100 feet from the shore and its south end about 4,000 feet from it, the length of the base being 28,992 feet approximately, or five and a half miles. Its height above the bay varies from 25 to 80 feet, the slopes of the ground being gentle, so that the inclination of the base-tubes reached 4° in but a single case. The latitude and longitude of its north end are 46° 57′ and 88° 27′.

Nearly the whole length of the base is through a forest, and the surface-soil is decomposed sandstone mixed with vegetable matter. Although the ground was tolerably firm during the measurement, greater stability for the trestles was obtained by making them rest on stout wooden stakes driven to the surface of the ground. The base-line had been converted into a rarely used road, and in places grass had sprung up. As stakes were used, the partial soil was not removed.

3. Comparisons of the tubes with the standard bar were made from July 16 to August 12, 1873; measurements, from August 13 to September 7, 1873; comparisons, from September 8 to September 11, 1873; measurements, from September 12 to September 25, 1873; comparisons, from September 26 to October 5, 1873; remeasurements from October 6 to October 8, 1873; comparisons, from October 9 to October 15, 1873.

The first distance of 94 tubes was measured four times at the beginning of the measurement and three times after the base had been finished, to ascertain the error in measurement.

From the preceding table it will be seen that as much time was required for the comparisons as for the measurement.

The computation of the length of the base was made in duplicate by Assistant Engineer E. S. Wheeler and Assistant Engineer R. S. Woodward. Thermometers and grade-angles were first corrected for their errors, and then the correction for grade-angles, contact-levels, expansion of tube 2, and error in cylindrical surface of tube 1, were summed and applied to the sum of the adopted lengths of the tubes. The resulting length was then reduced to the sea-level, giving for length of base 347,906.28 British inches. A correction for deviation from alignment and for contact-pressure will be applied in § 21.

4. The following markings of the base have been made: At south base the end point of the base is a cross on a piece of brass leaded into the top of a stone post six feet long, the top of the post being level with the ground. On the prolongation of the base southward, precisely one yard from the end of the base, is a cross on a piece of brass set in the top of a stone post two and a half feet long, the top of this post being six feet under ground. At right angles to the end of the base and about 100 feet east of it a six-foot stone post rises one foot above the ground.

There is a similar post about 100 feet west of the end of base, its top being broken off.

At the end of the ninety-fourth tube (1,410 feet) from south end of base, and on the base-line, there is a cross on brass in the top of a stone post 2½ feet long, the top of the post being 18 inches under ground.

At the middle of the base (end of nine hundred and fifty-second tube) there is a cross on brass in the top of a stone post, the top of the post being 2 feet under ground.

At the north end of base there is a cross on brass in the top of a stone post about three feet long, the post running down to rock and its top being 4 inches above ground. On the base-line and 28.4 inches south of the north end is a similar cross in a similar post, whose top is level with the surface of the ground. It is proposed to mark the north end of the base on the underlying rock. The present stone is about 30 feet from the road.

Some other stones were set on the base, whose descriptions will be found in the note-books.

Determination of lengths of tubes 1 *and* 2 *by comparisons with* 15*-foot standard bar.*

5. In these comparisons two objects were to be attained:

First, to determine the actual or working lengths of the tubes while employed in the measurement of the base.

Secondly, to find a correction to be applied to the lengths of the tubes used in the reduction of the Fond du Lac base, on account of the difference of exposure of the tubes during comparisons and measurement. The comparisons for that base were in a shed, the means of the lengths at maxima and minima temperatures of the standard bar being used in reduction, while the measurement was in the open air, the tubes being unprotected from the sun.

To reach the first end, each tube was compared with the standard bar in ice during several whole days, and the lengths of the tube obtained for each half-hour between 8 a. m. and 6 p. m., the usual working-hours. The mean of these for one day gave the length for that day. The tubes during these comparisons were under a tent, and as nearly as practicable under the same conditions as during measurement.

To reach the second end, the tubes under two thicknesses of canvas, and a part of the time wrapped in quilts, so as to approach the conditions of the Fond du Lac comparisons, were compared with the standard bar not in ice, at its maxima and minima temperatures.

Then the tents were removed, leaving the tubes exposed to the sun or clouds, and half-hourly determinations of the lengths of the tubes were made by comparisons with the standard bar in ice. The difference between the mean of the lengths of each tube derived from maxima and minima comparisons and the mean of those resulting from all day comparisons in the open air, is taken as the correction to be applied to the lengths of the tubes derived from maxima and minima comparisons at the Fond du Lac base, to give their working lengths during the measurement of that base.

6. The method of comparison was as follows: two contact level comparators, one by Würdemann and one by Stackpole, were mounted on heavy stone piers, a little more than 15 feet apart. The masonry supports of these piers rested on rock, and the piers were boxed nearly to their tops to protect them from unequal changes of temperature. A tube resting on its trestles was placed between the comparators, the standard bar was placed on the tube and carefully aligned, and then by the motions of the trestles one or the other was brought between the comparators, the Stackpole being kept at a fixed reading and the Würdemann comparator being read.

The stone piers proved to be very steady.

While the bar in ice was used its temperature is assumed at 32°; and judging from the apparent steadiness of the piers after correcting for expansion of comparators, this assumption must be nearly correct, the probable error in the bar temperature doubtless

being much less than in the determinations with the thermometer when the temperature of the air is not stationary.

When the bar was not in ice, its temperature was determined by mercurial thermometers.

In reducing, the thermometers were corrected for their errors, and then their curves plotted.

The readings on the standard bar and tubes were plotted as ordinates, times being the abscissas.

On inspecting the curves of comparisons of tubes with bar in ice when the temperature was above 65°, slight depressions are seen in the tube curve arising from the cooling effect of the bar during the five or ten minutes it was on the tube. In extreme cases, these depressions amount to $0^{in}.00040$. As the bar in ice was placed on the tube but once in two hours, the effect is eliminated by neglecting these depressions in the curves.

The differences between the tube and bar curves give the corresponding differences of length, and hence the length of the tube from the computed length of the bar at the observed temperature.

7. In all the following comparisons and in the computation of the length of the base the following assumptions have been made:

	in.
Length of standard bar at 62° F. in British inches	180.00972
Expansion of standard bar for 1° F.	0.00174
Expansion of Tube 1 for 1° F.	0.00000
Expansion of Tube 2 for 1° F.	0.00002

Any corrections to these values will be applied to the resulting length of base.

8. The following table gives the results of maxima and minima comparisons of Tube 1, and shows the increase in temperature of tube 1 for two hours before maximum or minimum temperature of bar.

Date.	Tube temperature.	Increase of temperature.	Maximum or minimum.	Length of Tube 1.
	°	°		in.
August 1, 1873	64.6	1.1	Maximum	179.9746
August 2, 1873	62.3	1.3	Maximum	386
August 9, 1873	63.6	0.6	Maximum	348
August 11, 1873	58.	0.0	Minimum	286
August 12, 1873	57.5	− 0.8	Minimum	229
October 13, 1873	52.	+ 2.3	Maximum	549
October 14, 1873	49.	+ 2.0	Maximum	444
October 14, 1873	37.6	+ 0.5	Minimum	176
October 15, 1873	45.7	+ 0.2	Minimum	229
Length of tube 1 from mean of maxima and mean of minima comparisons				179.97338

The difference between the means of the comparisons before and after October 12 is but $0^{in}.00031$, and is too small to be considered as making certain a change of length of Tube 1 in the interval. For this reason the mean of all has been taken.

The mean of the lengths at maxima exceeds that at minima by $0^{in}.00216$.

The corresponding difference for fourteen maxima and ten minima at the Fond du Lac base was $0^{in}.00150$.

As the errors in the comparator measurements could scarcely equal $0^{in}.00020$ in any case, the differences between the lengths given above are due mainly to the differences of temperature of the two compensating bars, and to the errors in determining the temperature of the standard bar.

9. The following table gives the daily means of lengths of Tube 1, taken every half-hour from 8 a. m. to 6 p. m., the tube having nothing over it to shield it from the sun.

Date.	Maximum tube temperature.	Minimum tube temperature.	Range.	Weather.	Length Tube 1.
	°	°	°		in.
August 4, 1873	90.5	64.5	26	Clear	179.97653
August 5, 1873	98.0	68.0	30	Few clouds	692
Mean					179.97672

Comparing this with (§ 8) the maximum and minimum length, $179^{in}.97338$, we have for correction on account of sun to the maxima and minima length of the Fond du Lac base, $0^{in}.00334$.

10. The following table gives the results of comparisons made to determine the working length of Tube 1 during the measurement of the Keweenaw base. Tube 1 was compared with standard bar in ice, and under a tent as in measurement. The table gives between 8 a. m. and 6 p. m. the maximum and minimum tube temperature and the mean length of the tube in that time.

Date.	Maximum tube temperature.	Minimum tube temperature.	Weather.	Mean length of Tube 1.
	°	°		in.
August 6, 1873	72.8	69.1	Cloudy	179.97482
August 7, 1873	65.0	62.0	Sunshine	490
August 8, 1873	66.	57.4	Sunshine	536
September 9, 1873	53.6	48.4	Light clouds	570
October 2, 1873	39.4	36.3	Cloudy	425
Working-length of Tube 1—mean				179.97501 ± 0in.000167

The maxima and minima comparisons (§ 8) indicating no permanent change of length of Tube 1, during the measurement the mean of the above values is taken as the working length of tube 1 during the whole of this measurement of Keweenaw base.

11. The following table gives the results of comparisons of Tube 2 with the standard bar at its maximum or minimum temperature, both being wrapped in quilts for a part of the time, and under two thicknesses of canvas. Increase of temperature for two hours before maximum or minimum is also shown.

Date.	Tube temperature.	Increase of temperature.	State of bar.	Length Tube 2
	°	°		in.
July 25, 1873	71.99	0.53	Maximum; in quilts	179.99836
July 26, 1873	58.89	0.00	Minimum; in quilts	884
July 26, 1873	69.28	0.60	Maximum; in quilts	915
July 29, 1873	68.87	1.02	Maximum; in quilts	916
July 30, 1873	57.93	0.07	Minimum; no quilts	941
July 31, 1873	61.54	1.70	Maximum; no quilts	953
October 11, 1873	45.65	0.03	Minimum	661
October 11, 1873	47.68	0.36	Maximum	631
October 12, 1873	32.65	0.72	Minimum	683
October 12, 1873	51.39	3.62	Maximum	669

The comparisons from July 25 to July 31 were before any measurements had been made, and those from October 11 to October 12 were after all measurements had been completed. The later comparisons show a large change in the length of Tube 2, and hence the first set should be used to determine the length at the beginning, and the second set that, at the close of the measurement.

	in.
The mean of the maxima comparisons before measurement is	179.99905
The mean of the maxima comparisons after measurement is	179.99650
Difference	0.00255
The mean of the minima comparisons before measurement is	179.99912
The mean of the minima comparisons after measurement is	179.99672
Difference	0.00240

Both alike indicate a large change in the length of the tube, and in § 12 it will be seen that the comparisons before and after measurement to determine the working length show the same change.

On September 11, one end of the tube fell; it was caught by hands, so that the blow on a man's shoulders below it was light, and therefore it received no great jar. It was at once carried to camp and recompared, but the comparison indicated no change of length.

It must then be assumed that the working length of Tube 2 was the same from the beginning of the measurement until September 11, and that all the change took place between this date and the close of the measurement.

Taking the half sum of the mean maximum and mean minimum length of Tube 2—

	in.
Before measurement, we have	179.99909
After measurement, we have	179.99661

The first is the length to adopt for Tube 2 before the measurement, from maximum and minimum comparisons; the second the corresponding length after measurement. Their difference measures the shortening of Tube 2, $0^{in}.00248$.

If the differences of the maxima and minima lengths before, and again after September 11, be taken, and then the mean of these, we have $-0^{in}.00015$ as the excess of length of this Tube 2 at maximum temperatures above that at minimum.

At the Fond du Lac base, this quantity was $0^{in}.00079$ as derived from six maxima and five minima comparisons.

12. The following table gives the daily means of the lengths of Tube 2, taken at each half-hour between 8 a. m. and 6 p. m., the tube being exposed to the sun or sky, and compared with the standard bar in ice. The standard bar was placed on the tube for five or ten minutes, once in about two hours, the piers being assumed to move uniformly if at all, in the interval.

Date.	Maximum tube temperature.	Minimum tube temperature.	Range.	Weather.	Length Tube 2.
	°	°	°		in.
July 17, 1873	76.5	64.5	12	Partially cloudy	180.0098[illegible]
July 21, 1873	90.5	61.5	29	Clear	16[illegible]
July 22, 1873	94.5	72.5	22	Partially cloudy	1[illegible]
Mean					180.0012[illegible]
From §11 the maxima and minima length before measurement was					179.9998[illegible]
Difference					− 0.00217

The difference $+0^{in}.00217$ is the correction on account of sunshine to apply to the length of Tube 2 used in computing the Fond du Lac base.

The corresponding difference for Tube 1, given in § 7, is $0^{in}.00334$.

The comparisons of Tube 1 were made in weather almost entirely clear, with constant sunshine; those of Tube 2 were on days, one of which was almost entirely clear, while on the other two there were heavy clouds for a part of each day. The mean is probably near the average value of the correction to the mean of the two tubes.

It will be remembered that Tube 1 is $0^{in}.00216$ longer at maximum temperature than at minimum, in consequence of its compensating bars heating at different rates, while tube 2 is $0^{in}.00015$ shorter. This difference of behavior in the two tubes also shows itself in the values of the quantities $0^{in}.00334$, and $0^{in}.00217$ just obtained.

13. The following table gives the daily mean working length of Tube 2, derived from its half-hourly lengths between 8 a. m. and 6 p. m. Tube was under tent, as in measurement, and was compared with standard bar in ice:

Date.	Maximum tube temperature.	Minimum tube temperature.	Length Tube 2.
	°	°	in.
July 18, 1873	60	53.	180.0008[illegible]
July 23, 1873	79	70.5	180.0015[illegible]
Mean			180.0003
September 30, 1873	43.5	35.5	179.9982[illegible]
October 1, 1873	42.5	37.0	179.9981[illegible]
Mean			179.9980

Showing a change in length of Tube 2 of $0^{in}.00263$. The change of length of Tube 2, shown by these comparisons, differs from that given by maxima and minima comparisons before and after measurement of the base by less than is to be expected from the probable errors of the comparisons.

As the working length comparisons after the measurement of the base were on September 30 and October 1, while the maxima and minima comparisons after measurement were on October 11 and 12, it follows that the change in length must have occurred between September 11 and September 30. The comparisons of September 11 not indicating that its length had been changed by its partial fall on that day, we must, for want of better data, assume that its length changed gradually from September 11 to September 30, and take for working length of tube 2 before the fall, on September 11, the value resulting from comparisons before measurement; for working length from September 11 till close of measurement, the mean of the working lengths given by comparisons before and after measurement; and for working length during the

remeasurements after October 1, the length resulting from comparisons of September 30 and October 1. These values are as follows :

	in.
Tube 2, working length before September 11	180.00083
Tube 2, working length September 11 to September 29	179.99951
Tube 2, working length after September 29	179.99820

14. An attempt will now be made to estimate the probable error in the working-length $179^{in}.97501$ adopted for Tube 1 during the remeasurement of the Keweenaw base.

On examining the daily curves resulting from the comparisons to determine the working length of this tube, it is found that the greatest change in length on any day between 8 a. m. and 6 p. m. during comparisons for working length was $0^{in}.00290$ on August 8, and the least change was $0^{in}.00094$ on August 7. These quantities give the change in length arising from varying differences of temperature between the upper and lower bar in the tube during the day, the tube being under canvas. Referring to § 10, it is seen that the greatest difference between the results of such comparisons on different days is $0^{in}.00145$, this difference resulting from the average temperature difference between the upper and lower bars of the tube being different on different days.

The differences arise from constantly varying causes, among which are cloudiness, humidity, wind, tent cover temperature, and earth temperature. While these causes are known, the amount of influence of each, on the length of the tube, is entirely unknown.

If it were certain that the conditions to which the tube was exposed during the whole of the measurement were fairly represented by those during the comparisons for working lengths, we might obtain the probable error in the adopted working length from the discrepancies between it and the single day's results, as if those discrepancies were accidental errors. The probable error thus found for working length of Tube 1 is $\pm 0^{in}.000167$.

The causes most effective in determining the daily fluctuations in the length of the tube are, the daily range of temperature, and the daily amount of sunshine. Now as these conditions were variable, the average daily temperature range in August being considerably greater than in the latter part of September; and the weather during the first period being very good, while in the latter there was much cloud and rain, giving lower and steadier temperatures, there is a considerable probable error involved in the assumption that the few days of comparison, fairly represented the many days of measurement.

During measurement the tube is over ground which in clear weather has for hours been exposed to the sun, while during working length comparisons, it is over ground continuously shaded by the tents. The earth's radiation will heat the lower bar most, thus partially neutralizing the effect of the sun acting through the tent on the upper bar, and shortening the tube below the length given by working length comparisons. The effect will vary so widely with the amount of sunshine and the nature of the ground, that it is impossible to estimate it. It must be many times less than that of direct exposure to the sun, which increases the mean daily length of the tube above the working length by $0^{in}.00171$.

Remembering that the greatest difference between any of the daily results of working-length comparisons was only $0^{in}.00145$, it would seem that the assumption of a probable error of $0^{in}.00030$ from the uncertainty in the action of the causes just mentioned must be ample. Combining it with that resulting from the comparisons we have

$$\pm \sqrt{(0^{in}.00017)^2 + (0^{in}.00030)^2} = 0^{in}.00034$$

as the probable error in the adopted value, $179^{in}.97501$, of the working length of Tube 1.

15. An estimate will next be made of the probable error in the working lengths adopted for Tube 2. It has already been stated that the mean of six maxima and minima comparisons between July 25 and 31, differs from the mean of four such comparisons on October 11 and 12 by $0^{in}.00248$, while mean of working length comparisons on July 18 and 23 exceeded that of such comparisons on September 30 and October 1 by $0^{in}.00263$.

Since there were ten of those to four of these, double weight is given to the first determination of amount of change, whence results—

Adopted decrease in length of Tube 2 = $0^{in}.00253$

On examining the curves plotted from the comparisons for working length, it appears that the greatest length of Tube 2 during a day's comparisons amounted to $0^{in}.00112$ on July 18, and the least change of length during a day was $0^{in}.00065$ on September 30, while the greatest difference of whole-day results was $0^{in}.00150$.

For reasons the same as in finding the probable error in working-length of Tube 1, that of Tube 2 is obtained in part from the discrepancies between the daily mean results and the final mean. But as the tube changed length by $0^{in}.00253$ before the compari-

sons of September 30 and October 1, that amount has been added to the results of those days before deducing the probable errors, as the number of results before or after measurement, taken separately, was too small. This process tacitly assumes that the precise change in length of Tube 2 is known; the error in the assumption must be small, and would have little effect on the following value of the probable error.

By this method there results:

Probable error in working-length of tube 2 deduced from comparisons $= \pm 0^{in}.00021$.

For the reasons stated in § 14, a probable error of $0^{in}.00030$ is assumed to cover the difference between the external conditions during measurement and during working-length comparisons.

Combining the two errors we have—

$$\pm\sqrt{(0^{in}.00021)^2+(0^{in}.00030)^2} = \pm 0^{in}.00037$$

as the probable error in the working lengths adopted for Tube 2.

16. Alignment was obtained after finding that the mark at the middle base was very nearly on the line through the marks at the ends of the base by setting up a theodolite at the middle of one of the halves of the base, very nearly on the line; then reading by several repetitions the angle (very nearly 180°) between the ends of this half and computing the distance the stake must be moved to bring it on the line. Each of these smaller parts was then bisected in the same way, and the process continued till stakes had been set on the line 500 feet apart. By this method it is improbable that any of those lines could have been inclined to the base-line by more than one minute, as the instrument used read to 10 seconds, and the probable error is much less. As an error of one minute would only introduce an error into that part of the base of $\frac{1}{2000000}$, and as the probable error is much less, it is insignificant in comparison with other errors, and may be neglected, or, what is the same thing, these stakes 500 feet apart may be assumed to be precisely on the line.

To place a tube on the line, the base-line transit-instrument, with a more powerful telescope than that of the theodolite, was set up on one of the stakes and pointed at the preceding, and the front end of the tube placed in the vertical plane of the telescope. When the front tube got within 150 or 200 feet of the transit, the latter was moved to the next 500-feet stake. The distances from transit to tube varied then from 200 to 700 feet.

The length of the base gives 57 of these 500-feet intervals, and so many times will the distance of the tubes from the transit vary from 700 to 200 feet.

The maximum error that could be committed in putting the agate at the end of the tube on the line at the distance of 700 feet may be taken as $0^{in}.3$, and at the distance of 200 feet as $0^{in}.05$.

From the ordinary law of error, when the maxima errors in 57 observations are respectively $0^{in}.3$ and $0^{in}.05$, we have the probable errors of one such observation respectively $0^{in}.08$ and $0^{in}.013$.

These values give for the probable deviation from the base-line of a tube at 700 feet from the transit—

$$\frac{0.08\sqrt{2}}{180} = 130''$$

and at the distance of 200 feet—

$$\frac{0.013\sqrt{2}}{180} = 21''$$

For 130″ the correction to the length of a tube would be only $\frac{1}{5000000}$ part of its length, and taking—

$$\frac{130''+21''}{2}$$

as the probable deviation of any tube, the probable correction to each tube is—

$$-0^{in}.000012$$

This correction always being negative, its value for the whole base is—

$$1933 \times (-0^{in}.000012) = -0^{in}.023$$

The probable error in this correction is so small in comparison with other probable errors that it may be neglected.

17. The inclination of the tubes to the horizon is read to seconds by means of the sector. The sector is liable to get out of adjustment, and this adjustment was therefore examined and the correction determined every few days during the remeasurement, eighteen times in all for each tube. The maximum correction found was 115 seconds. The error in the adopted value for any inclination will therefore be made up of two parts: first, the error in the determination of the correction; secondly, the error in the assumption that between two such determinations, the correction changed uniformly.

The correction was determined by bringing the two agates at the ends of a tube into

the same horizontal plane by means of a leveling-instrument close at hand, and then reading the sector. Repeated trials gave a range to the values of the correction of less than twenty seconds; and as several determinations were made each time the correction was determined, if five seconds be taken as the probable error of the correction it is certainly large enough.

If the mean value of the correction as derived from its consecutive determinations were used, the resulting correction to the tubes would be nearly the same as if the correction was supposed to change uniformly. The probable error of this mean value would be—

$$\frac{5''}{\sqrt{2}} = 3''.5$$

giving for the length of one tube a correction of $0^{in}.000107$, if its inclination be taken at 2°. This value 2° is more than double the average inclination and is certainly large enough to more than balance the greater effect of the error in inclination in the few larger grade angles. There being thirty-six determinations of the correction, we may consider the line as divided into steps whose average length was 53 tubes. In this distance, the probable error in the length will be—

$$53 \times 0^{in}.000107 = 0^{in}.00567$$

and for 36 steps, or the whole base—

$$\sqrt{36} \times 0^{in}.00567 = 0^{in}.034$$

There is another error in the assumption that between two determinations of the sector-correction, that correction varies uniformly.

There is no method of judging of the amount of error in the assumption; but as the correction was sometimes constant for several days, (once for ten days,) if 10″ be taken as the probable average constant error in any set of 53 tubes from this cause, it would seem to be ample.

As in the 1,933 tube lengths which made up the base, 1,834 had an inclination of less than 2°, we shall give more than the full effect to this error by taking 2° as the inclination of all the tubes in its computation. This probable error of 10″ gives a probable error of—

$$\frac{10''}{3''.5} \times 0^{in}.034 = 0^{in}.097$$

in the whole base.

The resultant error in the base arising from both these inclination-errors is then—

$$\sqrt{(0^{in}.097)^2 + (0^{in}.034)^2} = 0^{in}.103$$

18. When at any time from the approach of night, or from bad weather, the measurement was suspended, the terminal point of the measurement was marked by a cut in the head of a copper tack driven into the head of a stake; this head being below the surface of the ground.

To fix the position of this mark, a theodolite was set up a short distance from the front agate of the advanced tube in a plane through the end of the agate normal to the line of tube; and after leveling the theodolite, the end of the agate was pointed at, and the mark on the tack-head made, in the same vertical plane, the tack having been already placed in the vertical plane of the base line.

In thus referring the end of the tube to the ground with a good theodolite, experience shows that an error greater than $0^{in}.03$ is impossible. A similar error may arise in placing the rear end of the rear tube over the mark on the copper tack when the measurement is resumed. Assistant Engineer E. S. Wheeler is of opinion that the greatest error did not exceed $0^{in}.02$.

There were 44 references of tube to ground or from ground to tube; and assuming the ordinary law of error to hold, and that the maximum error in such references was $0^{in}.03$, we have for the probable error in one reference $\pm 0^{in}.009$, and the probable error in the length of the base arising from this cause, $\pm 0^{in}.06$.

19. There is an error entering into every measurement of one tube length, arising from the pressure of contact between consecutive tubes. This pressure, when reduced to the lowest amount consistent with certainly overcoming the friction of the sliding-rod, was still four ounces.

Now, supposing a standing tube to be in the right position; when the next tube is brought into contact with it, the pressure between the two forces back the rear or standing tube by a certain amount, and, of course, the front tube is moved back in contact by the same amount; now, when the rear tube is taken away, the front tube is relieved from the pressure of contact, and moves to the rear by the same amount, and is then the standing tube, but is a distance in rear of the position it would have had if the contact-pressure had been zero, by twice the disturbance produced by the contact-pressure. The amount of this disturbance will vary with the precision with which the movable parts of the trestles fit each other, and with the height to which the tube is raised by the vertical motion of the trestles. From nearly a hundred

determinations of the amount of displacement, made by Assistant Engineer E. S. Wheeler and Assistant Engineer Burton in 1872 and 1873, the following mean values have been obtained for disturbance by pressure of contact, that pressure being about four ounces: the trestle being either run up to its full height, or run clear down;

Trestle up, $0^{in}.00034$; trestle down, $0^{in}.00013$.

During the remeasurement of the Keweenaw base, the trestles were kept as low as possible, the average being estimated at one-fifth their total range, and hence giving $0^{in}.00017$ as the average displacement. Doubling and multiplying by 1932, the number of tubes less one, there results a correction to the length of the base of $-0^{in}.657$.

Taking into consideration the varying conditions, as cleanness of the movable parts of the trestles, firmness of ground support, and the difficulty of measuring with precision movements so small as $0^{in}.00017$, its probable error may easily be $0^{in}.00013$ or $0^{in}.00004$. Taking the latter, we have for the correction to the measurement of the base $-0^{in}.657 \pm 0^{in}.109$.

20. The change in length of tube 2 between the middle base and north base has already been referred to.

In the computation of the length of the base, it has been assumed that this tube changed length uniformly from September 11 to the end of the measurement of the base, which gives the same result as the assumption that the change was instantaneous midway between these points.

The maximum error in this assumption would exist if the change in length had been instantaneous, and on September 11, or just after the close of the measurement, and would amount to $490 \times 0^{in}.00129$ or $0^{in}.632$. In view of the uncertainty as to whether the change was instantaneous, and, if so, at what time it occurred, it is deemed best to assume that the probable error in the length of the base from this cause is one-fourth the maximum error possible, namely, $\pm 0^{in}.158$.

21. The chief sources of error in the determination of the working lengths of the tubes by comparisons with the standard bar, whose length is supposed known, and in the actual measurement of the base, have now been considered.

The probable errors in the length of the base resulting from the various causes are as follows:

§ 14. From probable error in length of Tube 1: $967 \times 0^{in}.00034$	$0^{in}.329$
§ 15. From probable error in length of Tube 2: $966 \times 0^{in}.00037$	$0^{in}.357$
§ 17. From probable error in inclinations	$0^{in}.105$
§ 18. From probable error in reference to and from ground	$0^{in}.052$
§ 19. From probable error in contact-displacement	$0^{in}.109$
§ 20. From probable error in change of length of Tube 2	$0^{in}.158$

Taking the square root of the sum of the squares of these quantities, we have for the probable error in the length of the base arising from these causes $\pm 0^{in}.535$, or $\frac{1}{\quad}$ part of the base.

The length of the base reduced to the sea-level and uncorrected for the displacement of contact, as computed, is 347,906.28 British inches.

Applying the correction $-0^{in}.657$ for displacement by contact, (§ 19,) and $-0^{in}.023$ for deviation from alignment, (§ 16,) this becomes $347,905^{in}.60 \pm 0^{in}.535$.

22. To obtain an actual test of the precision with which a measurement could be repeated, the first 94 tubes, or 1,410 feet, were remeasured four times before and three times after the measurement of the base.

The following table gives the results:

Measure.	Temperature.			Weather.	Length.
	Max.	Min.	Mean.		
	°	°	°		in.
First	82	67	73.9	Rather cloudy	16,913.[illegible]
Second	71	67	69.6	Clear	.[illegible]
Third	82	63	72.9	Mostly clear	.[illegible]
Fourth	66	54	61.2	Cloudy	.[illegible]
Fifth	58	39	49.3	Clear	.[illegible]
Sixth	71	40	60.8	....do	.[illegible]
Seventh	68	54	62.0	....do	.[illegible]
Mean					16,913.[illegible]
Mean first four					.[illegible]
Mean last three					.[illegible]

Deducing the probable error of a single result, it is found $0^{in}.032$, or $\frac{1}{x,xxx,xxx}$.

It will be noticed that in these measurements the mean temperature varied from

49°.3 to 73°.9; that the range of temperature during a measurement varied from 4° to 31°, and the weather from steady clear to entirely cloudy.

These extreme variations in mean temperature and daily ranges should develop in the fullest degree any errors arising from the expansions of the tubes, or in the value adopted for change of the working-length of Tube 2; and as these extreme variations doubtless give more discrepant results than the ordinary variations during measurement, it may be expected that the probable error deduced for one measurement of the 94 tubes, $\frac{1}{3\,5\,0\,0\,0\,0}$, is larger than actually existed in the main measurement arising from the same causes. There are some errors which would not reveal themselves in these measurements of 94 tubes:

First, the displacement by contact, which would remain the same in all of them.

Secondly, a constant error in the working length of the tubes used in the computation.

Taking the values adopted for these errors in §§ 14, 15, 19, we have for the errors from the two causes, introduced into the measurement of 94 tubes, $\pm 0^{in}.004$, $\pm 0^{in}.016$, and $\pm 0^{in}.0.20$,

$$\sqrt{(0^{in}.032)^2 + (0^{in}.004)^2 + (0^{in}.016)^2 + (0^{in}.020)^2} = 0^{in}\ 041$$

is therefore the probable error of one of these measurements of 94 tubes, or $\frac{1}{8\,5\,0\,0\,0\,0}$ part of its length.

Remembering that while for some of the errors the effect increases with the length measured, for others it increases only as the square root of the length; and remembering also that the probable error $0^{in}.032$ derived from measurements made under extreme variations of temperature, is undoubtedly larger than for measurements under ordinary conditions, it does not seem that the accuracy deduced in § 21, for the actual measurement, namely, $\frac{1}{3\,5\,0\,0\,0\,0}$, is too large.

But to include the effect of any errors not considered in deducing that value, and to underestimate rather than overestimate the accuracy of the measurement, the value $\frac{1}{3\,0\,0\,0\,0\,0}$ will be adopted.

The length of the Keweenaw base reduced to the sea-level is then 347905.60 ± 0.696 British inches, provided the standard 15-feet bar has the length $179^{in}.95752$ when packed in melting ice.

A slight correction to this length, and hence to the base, as well as in consequence to its probable error, will be applied when a final value for standard bar is adopted.

23. A check, though not a very precise one, was obtained by erecting a station at middle base, and reading the angles of the two triangles into which the main triangle, North Base—South Base—Quaquaming, was thus split. Unfortunately, as these small triangles did not form a part of the main triangulation, fewer readings of their angles were made, and the angles were not thoroughly determined. There was no quadrilateral.

On computing with these angles the south half of the base from the measured north half, the result was $176584^{in}.31$, which is $2^{in}.08$ shorter than the measured length. This discrepancy would be accounted for by supposing an error of $1''.3$ in the angle opposite the north half of the base.

The data used in this paper will be found in office-reports Nos. 255 and 282.

C. B. C.

APPENDIX F.—EXAMINATION INTO THE ACCURACY OF THE SCREW OF THE WÜRDEMANN COMPARATOR.

Report of Lieut. D. W. Lockwood, Corps of Engineers.

UNITED STATES LAKE SURVEY STEAMER ADA,
July 8, 1874.

MAJOR: I have the honor to make the following report with regard to the value determined for one turn of the micrometer-screw of the Würdemann comparator, used in connection with the base line tubes of the Lake Survey, and also with regard to the constants to be used in correcting the readings of the micrometer-head for periodic errors of the screw.

The method adopted in determining the first set of values was as follows:

The comparator was firmly mounted on a stone post in the basement of the Lake Survey building, and carefully leveled. A silver inch-scale, divided to tenths, the values of which had previously been determined by Mr. Hilgard, of the Coast Survey, was then laid upon the slide carrying the pointer of the comparator-scale, and adjusted so that the line of the graduated edge of the scale should move parallel to the line of micrometer-motion. A reading-microscope, from the Repsold theodolite in the office, was adjusted over the silver inch-scale, and the tenths of the comparator-scale compared with the different tenths of the silver inch. The latter is graduated on both sides; the lines

on one side being much heavier than those on the other. The coarse side only was used, as some of the lines have entirely disappeared on the fine side, while nearly all of them were found to be imperfect in some part of their length. The scale is somewhat beveled, or rounded on the graduated edge, and it was also found that some of the lines were not perpendicular to it. In consequence of these facts, only those tenths were used in making comparisons which were marked by the best lines. The cut 0.6 was found to be 0.00272 of an inch in width, taking the least reading of the comparator-micrometer to be 0.00001 of an inch, from which it does not vary sufficiently to be appreciable, in measuring so small a distance. Some of the cuts are narrower, and the mean width of all is from 0.002 to 0.0025 of an inch. The apparatus for holding the microscope in position over the comparator was a wooden affair; the adjustments for centering the microscope being effected with wooden wedges. The illumination was by means of an ordinary bull's-eye lantern, held in position by the frame that supported the microscope.

At 0.45 on the comparator there was required a marked increase of force to turn the screw, and the slide carrying the pointer was twisted so as to draw the edge of the silver scale away from the longitudinal wire of the microscope and toward the comparator-scale. This would seem to indicate an unequal degree of compression in the spiral springs which press against the slide. On taking the instrument apart, it was found that the spring on the side opposite to the comparator-scale was coiled much closer than the other, and became compressed fully at about 0.45. No observations are therefore adopted that extend beyond the 0.4-inch mark on the comparator-scale. Twenty measurements were taken for each set of comparisons.

The following are the results obtained, the first column showing the space on the silver scale, the second column showing the space on the comparator-scale, and the third the result obtained by dividing the value of the space in the first column, expressed in terms of the United States inch as given by Mr. Hilgard, by the micrometer-value obtained of observation:

Silver scale.	Comparator-scale.	Value of 0.1 of comparator-scale.			
0.0 to 0.1	0.0 to 0.0	0.1004848			
.0 .1	.1 .2	.1003738			
.0 .1	.1 .2	.1003909	0.1003958		
.0 .1	.1 .2	.1004227			
.0 .1	.2 .3	.1004111			
.0 .1	.2 .3	.1004131	.1004121	0.1004024	
.0 .1	.15 .25	.1004121	.1004121		
.0 .1	.25 .35	.1004096	.1004096		
.0 .1	.3 .4	.1003824	.1003824		0.1003673
.1 .2	.2 .3	.1003649	.1003491	.1003491	
.4 .5	.1 .2	.1003346	.1003346	.1003346	
.4 .5	.2 .3	.1003346			

It will be seen from the above table that, taking the values for the different tenths on the comparator-scale, as determined by comparison with the same tenth on the silver scale, the range is quite small, while decidedly the reverse obtains when different tenths of the silver scale are used. From this it would appear that either the values given for the different tenths on the silver scale are not correct, or that the pointings were not made to the same parts of the cuts when the comparisons were made as when the values of the tenths were determined.

The value of space 0.0 to 0.1 on the comparator is thrown out because the compression-springs acting on the slide that carries the pointer of the scale are, between those two points, so slack as to exert but little or no force. The comparator should be used to measure distances only between the 0.1 and 0.4 cuts.

The following table shows the values of the different tenths of the silver inch (coarse side) as furnished by Mr. Hilgard, United States Coast Survey:

	U. S. inch.		U. S. inch.
0.0 to 0.1	0.10001	0.5 to 0.6	0.09998
.1 .2	.10066	.6 .7	.09986
.2 .3	.10001	.7 .8	.10026
.3 .4	.09961	.8 .9	.10023
.4 .5	.10028	.9 .10	.09969

The value of one turn of the comparator-micrometer is 0.02 of the comparator-inch; its head is divided into 200 parts, which are read to tenths by inspection, making the least reading 0.00001 of the comparator-inch.

PERIODIC ERROR OF SCREW.

Determinations with a micrometer-screw presuppose not only the knowledge of the value of one turn, but also that the motion of the screw shall be proportioned to the divisions on its head, a condition, of course, that is never precisely fulfilled, and there is in consequence a small correction to be applied to each reading on the head, which may be taken as of the form—

$$a_1 \cos u + b_1 \sin u + a_2 \cos 2u + b_2 \sin 2u$$

where, for several consecutive turns, a_1, b_1, a_2, b_2, may be considered as very nearly constant.

If in measuring a distance, f, we obtain the readings u, u', we have—

$$f = (u' - u) + a_1(\cos u' - \cos u) + b_1(\sin u' - \sin u) + a_2(\cos 2u' - \cos 2u) + b_2(\sin 2u' - \sin 2u) \quad (1)$$

while a nearly correct value of f can be found by measuring f, starting from different parts of the screw, viz, beginning at 0.0, 0.1, 0.2, 0.3, . . ., 0.9, turns of the screw in succession, and taking the means of the values of f thus determined.

This value of f will differ so little from $u' - u$ that in the factors of the small quantities a_1, b_1, a_2, b_2, we may replace u' by $u + f$, and eq. (1) becomes—

$$(u' - u - f) = 2a_1 \sin\frac{f}{2} \sin\left(u + \frac{f}{2}\right) - 2b_1 \sin\frac{f}{2} \cos\left(u + \frac{f}{2}\right) + 2a_2 \sin f \sin(2u + f) - 2b_2 \sin f \cos(2u + f)$$

by substituting for $\sin f \cos f$ their equivalents in terms of functions of $\frac{f}{2}$

If we write out this equation for all ten measurements, treat the resulting equations as equations of condition by the method of least squares, a_1, b_1, a_2, b_2, being the unknowns, and remember what the values of sums of sines, cosines, and their products, when the angles are uniformly distributed through 360°, become, we shall have the following normal equations:

$$10\, a_1 \sin\frac{f}{2} = \Sigma\,(u' - u - f) \sin\left(u + \frac{f}{2}\right)$$

$$10\, b_1 \sin\frac{f}{2} = \Sigma\,(u' - u - f) \cos\left(u + \frac{f}{2}\right)$$

$$10\, a_2 \sin f = \Sigma\,(u' - u - f) \sin(2u + f)$$

$$10\, b_2 \sin f = \Sigma\,(u' - u - f) \cos(2u + f)$$

from which the values of a_1, b_1, a_2, b_2, can be found.

The above is the method adopted by Bessel in determining the value of the heliometer-screw at Königsberg, and given in his "Astronomische Untersuchungen." He took once a distance of about one-half of a turn of the screw, and once a distance of about one-fourth of a turn, and measured each distance 100 times, beginning, each time, 0.1 of a turn farther ahead on the screws.

It will be observed that $f = 180°$ makes $10\, a_2$ and $10\, b_2 = \infty$, unless—

$$\Sigma\,(u' - u - f) \sin(2u + f)$$

and—

$$\Sigma\,(u' - u - f) \cos(2u + f)$$

become equal to 0. In consequence of this, in taking a distance equal to *about* one-half turn, its value should be such as to make the value of $\sin f$ an appreciable quantity.

In determining the values of a_1, b_1, a_2, b_2, for the micrometer-screw of the Würdemann comparator, the same conditions with regard to arrangement of microscope and adjustment of comparator were observed as in determining the value of one turn. A glass scale divided to about the $\frac{1}{100}$ of an inch was laid on the slide, and a distance of about one-half turn having been selected, this distance was measured 25 times, starting from each origin. The point on the screw selected as the initial point was 0.14.

A distance of about one-fourth turn was then taken, and measurements made of it in the same manner.

The following are the results obtained:

About ½ turn:	About ¼ turn:
0.50290	0.24924
.50170	.24982
.50074	.24866
.49934	.24538
.49898	.24498
.49940	.24510
.49974	.24688
.50014	.24850
.50236	.24946
.50414	.24988
Mean, 0.500944 (or $f = 180° 20' 23''.4$)	Mean, 0.247789 (or $f = 89° 12' 15''.2$)

First set gives $a_1 = .001045$, $b_1 = -.0004141$ } ½ turn.

Second set gives $a_1 = .0006837$, $b_1' = -.0016839$, $a_2' = -.0001752$, $b_2 = .0003137$ } ¼ turn.

a mean of which gives—

$$a_1 = 0.00086643,\ b_1 = -0.001049\ a_2 = -0.0001752,\ b_2 = .0003137$$

and the corrected value of any reading u will be—

$$u' = u + 0.000864 \cos u - 0.001049 \sin u - 0.0001752 \cos 2u - 0.0003137 \sin 2u$$

The values of a_2 and b_2 as determined by the first set were thrown out, the factor $\sin f$ being so small. In the above expression u is the reading as given on the micrometer-head, from which the angle u is readily obtained, while the constants are expressed in terms of one turn as a unit, the approximate value of which is about 0.02 of an inch, (comparator.)

In the foregoing discussion, by an inch is meant the United States standard inch, unless otherwise expressed.

The observations from which the foregoing results are obtained were taken at various times from January 22 to May 2, 1873.

Respectfully submitted.

D. W. LOCKWOOD,
First Lieutenant of Engineers.

Maj. C. B. COMSTOCK,
Corps of Engineers, U. S. A.

APPENDIX G.—RESULTS OF TESTS OF THERMOMETERS.

Report of Mr. T. Russel, Assistant Engineer.

OFFICE UNITED STATES LAKE-SURVEY,
Detroit, Mich., January 22, 1874.

GENERAL: I have the honor to submit the following report concerning the determination of boiling and freezing points of standard thermometers, and the comparisons of standard Troughton and Simms No. 230 with various other thermometers.

The scale of standard Troughton and Simms No. 230 is graduated on the glass tube through which the column of mercury rises. The tube is cylindrical, and on the side directly opposite the graduation there extends throughout its entire length a strip of white-colored glass, so that in reading, the column of mercury and graduation are projected on a white background. This standard has no attachments of metal or any other material. Its length is 16.4 inches and its diameter 0.3 of an inch. The bulb is elongated, the greatest diameter being 0.85 of an inch and its least 0.20 of an inch. It is graduated to whole degrees Fahrenheit from +20° to +220°. The length of a degree is 0.067 of an inch. When not in use, the thermometer is inclosed in a black lacquered brass case lined with soft rubber.

This standard was tested at Kew observatory, and the following system of corrections found for thermometer vertical:

JANUARY, 1872.

Standard Troughton and Simms No. 230.

Temperature.	Correction.
°	°
32	0.0
42	0.0
52	—0.1
62	0.0
72	+0.1
82	+0.2
92	+0.3
212	+0.1

The above corrections are to be applied to the scale-reading of the thermometer. The freezing point of standard No. 230 was tested August 18, 19, and September 11, 1873. The boiling point was tested October 15, 16, 21, and 22, 1873. The boiling point was again tested November 17 and 18, 1873, each determination of boiling point being followed by a determination of freezing point. The freezing point was again tested December 19 and 20, 1873, and January 6, 1874.

For the purpose of testing the freezing point, a box was filled with pounded ice, the coarse pieces being at the bottom, the finer material toward the top, and especially in the position to be occupied by the thermometer-bulb. In the bottom of the box were a number of holes, which provided an escape for the melted ice. On opposite sides of the box strips were nailed, extending fourteen inches above the top, and supporting a cross-piece, from which the thermometer was suspended. The thermometer-tube was made vertical by aligning with a plumb-line, securing it in this position, and then packing the ice around the bulb and tube, allowing only so much of the mercurial column to project as to admit of its being read.

The reading of the thermometer was made with a telescope of short focus, so arranged that the line of sight was horizontal. In reading, the telescope was at a distance of two and one-half feet from the thermometer. The magnifying-power at this distance was 35. In the following results, the fractional part of the degree was estimated.

Determination of freezing point.—Standard, Troughton and Simms No. 230.

Date, 1873.	Reading of No. 230.	Correction to No. 230.
Aug. 18....	32.15	—0.15
Aug. 19....	32.15	—0.15
Sept. 11....	32.17	—0.17
Mean		—0.16

The apparatus for testing the boiling point was constructed on the principle of that used for the same purpose by the celebrated French physicist Regnault. Its height was such that when the reservoir was full of water at a temperature of 212° Fahrenheit, the bulb was 1.5 inches above the surface, enough of the tube projecting at the top to show graduation 209°. On account of only such a small portion of the tube projecting from the vessel, it was impossible to adjust the thermometer-tube perpendicularly with all the accuracy desirable. Errors, arising from a deviation of the tube from the perpendicular, on account of parallax, there being a considerable distance between the mercurial column and graduation, are probably eliminated in taking the mean of several observations.

Lake-Survey standard barometer 1274, James Green, was used for determining the atmospheric pressure. The barometer was suspended in a room adjoining the one where the thermometer was being tested. The level of the mercury in the cistern was within a few inches of the same level as that of the water in the boiling apparatus. The instrument was fixed in a vertical position and secured, so that in adjusting the level of the mercury in the cistern the instrument was steady.

In the room where the barometer was suspended, there was found to be considerable variation in the temperature of the air at different heights above the floor. On this account, two additional thermometers were used, one a foot above and the other a foot below the attached thermometer; but in the reduction for temperature the attached thermometer was given double weight. The correction to these two additional thermometers to reduce to true temperature was found to be —0.2 of a degree at 62° Fahrenheit. The corrections to be applied to the various observations of barometer, to reduce to 32° Fahrenheit, were taken from Guyot's "*Tables météorologicales et physicales.*" In James Green's barometers, allowance is made for capillarity in setting the scales, and there is therefore no correction required. The Lake Survey Report for 1861 gives a series of comparisons made by W. C. Bond between Lake-Survey barometer 1274 and standard barometer, No. 57 Newmann, of Cambridge observatory. The mean of the results of these comparisons gives a correction of — 0.006 of an inch to be applied to the reading of barometer 1274 to reduce to the indication of standard No. 57. Cambridge standard No. 57 had been previously compared with Royal Society standard, and there was found to be no difference between them.

The correction to be applied to barometer 1274 to reduce to true barometric height is, therefore, — 0.006 of an inch.

The line 212° on Fahrenheit thermometers represents the temperature of steam under a standard atmospheric pressure, or a barometric reading in the latitude of 45° at sea-level of 0.760 of a meter after correction to 32° Fahrenheit. This pressure in any other latitude, λ, will be represented by a column of mercury whose height is—

$$0^{m}.760\ \frac{\text{gravity at } 45^{\circ}}{\text{gravity at } \lambda}$$

or, adopting the length of the meter as 39.3704 English inches, this pressure in the latitude of Detroit, $\lambda = 42^{\circ}\ 20'$, will be represented by a column of mercury whose height is—

$$29^{in}.9215\ [1 + 0.002625 \cos 2\ (42^{\circ}\ 20')] = 29^{in}.9238$$

This supposes the barometer to be at the level of the sea. The observing room at Detroit being at an altitude of 600 feet above the level of the sea, the change in the intensity of the force of gravity for this elevation would cause the barometer to read 0.0017 of an inch greater than at the level of the sea.

The attraction of the matter between the level of the sea and the place of observation would also cause a sensible difference in the height of the barometer.

The attraction of a cone for a particle situated at its vertex is given by the expression—

$$A = 2\ \pi\ h\ \delta\ (1 - \cos \gamma)$$

where A is the attraction of a cone, δ its density, h its altitude, and $2\ \gamma$ its vertical angle. Representing by G the force of gravity at the level of the sea, and supposing the cone to be half the mean density of the earth, we have, since the attraction of a sphere for a particle situated on its surface is equal to $\frac{4}{3}\ \pi$ R times its density, R being the radius—

$$G = \tfrac{2}{3}\ \pi\ R\ \delta$$

so that the entire amount by which the force of gravity is affected by the attraction of a cone is—

$$\frac{A}{G} = \tfrac{1}{2}\ \frac{h}{R}\ (1 - \cos \gamma)$$

Detroit being situated on an elevated plane, the vertical angle of the cone, $2\ \gamma$, may be considered as 180°, and the above expression becomes—

$$\frac{A}{G} = \tfrac{1}{2}\ \frac{h}{R} = 0.00002$$

This causes the barometer to read 0.0006 of an inch less.

The sum of these corrections gives, to reduce barometer to latitude 45° to sea-level and allowance for matter between barometer and sea-level, the quantity —0.006 of an inch.

In the determinations of boiling point, made November 17 and 18, distilled water was used. In those made in October, the water was obtained by melting ice.

In the determinations of boiling point, made in October, the reading of the thermometer was effected by means of a telescope of short focus, the fractional part of the degree being estimated.

Determination of boiling point of standard Troughton and Simms No. 230.

Date.	Time of observation.	Mean of barometer readings.	Mean of attached thermometer readings.	Barometer reduced to 32° F.	Barometer at sea-level.	Boiling point.	Observed boiling point.	Correction.
1873.	*h. m.*	*in.*	°	*in.*	*in.*	°	°	°
October 15	0 40	29.847	74.4	29.725	29.711	211.65	211.55	+0.10
October 15	3 15	29.833	90.2	29.669	29.655	211.55	211.49	.06
October 15	3 40	29.802	77.7	29.671	29.657	211.56	211.48	.08
October 16	10 35	29.650	69.3	29.542	29.528	211.34	211.30	.04
October 16	11 38	29.628	70.8	29.516	29.502	211.29	211.25	.04
October 16	1 12	29.598	71.9	29.483	29.469	211.24	211.15	.09
October 21	10 50	28.733	49.2	28.679	28.665	209.85	209.77	.08
October 21	11 38	28.742	50.7	28.685	28.671	209.86	209.80	.06
October 22	11 15	29.280	59.8	29.206	29.192	210.76	210.76	.00
October 22	12 10	29.284	59.6	29.202	29.188	210.75	210.75	+0.00
Mean								+0.06

In the determinations of boiling and freezing points, made November 17 and 18, the readings of the thermometer were made with Würdemann theodolite No. 68, provided with a micrometer, by means of which the fractional part of a degree was ascertained to at least 0.01. In reading, the instrument was at a distance of five feet from the thermometer, and so arranged that the line of sight of the telescope was nearly in the same horizontal plane as the top of the column of mercury. In testing the boiling point, the water was allowed to boil about twenty minutes before any readings were made. The process of observation was first to read the barometer and attached thermometers; next to ascertain the indication of the manometer attached to the vessel, and which denoted the excess of pressure within over that outside. The micrometer was then read at the graduation below the top of the column of mercury, at the top of the column, and at the graduation immediately above the top of the column. Five micrometer measurements were usually made, the time being noted at the first and the last. After the fifth micrometer measurement, the manometer was again observed, and another reading of barometer made. Every time the thermometer was raised to the boiling-point, three sets of observations were made, each consisting of five micrometer measurements, and each set preceded and followed by an observation of the barometer and the manometer. The average length of time required in making five micrometer measurements was four minutes. In only a few instances the manometer indicated a pressure inside the vessel greater than the pressure outside. Proper allowance was made for this in the reduction. The amount of pressure, when there was any excess, was usually equivalent to about 0.005 of an inch of barometric pressure, which corresponds to 0.01 of a degree in the boiling point.

Determination of boiling point of standard Troughton and Simms No. 230.

Date.	Time of observation.	Mean of barometer readings.	Mean of attached thermometer readings.	Barometer reduced to 32° F.	Barometer at sea-level.	Boiling point.	Observed boiling point.	Correction.
1873.	*h. m.*	*in.*	°	*in.*	*in.*	°	°	°
November 17	10 05	28.849	54.3	28.782	28.768	210.03	209.93	+0.10
November 17	10 16	.851	54.7	.783	.769	.03	.91	.12
November 17	10 23	.852	55.0	.783	.769	.03	.92	.11
November 17	12 45	.844	61.8	.758	.751	210.00	209.90	.10
November 17	12 52	.843	61.7	.757	.750	.00	.90	.10
November 17	1 00	.845	62.3	.758	.751	.00	.91	.09
November 18	10 19	.772	55.8	.701	.687	209.89	.87	.02
November 18	10 28	.775	56.5	.702	.688	.89	.85	.04
November 18	10 33	.776	56.6	.704	.690	.90	.88	.02
November 18	11 44	.778	58.1	.702	.688	209.89	.83	.06
November 18	11 51	.777	57.9	.702	.695	.91	.82	.09
November 18	11 57	.778	57.8	.703	.696	.91	.82	.09
November 18	1 32	.780	57.0	.706	.696	209.91	.85	.06
November 18	1 40	.785	57.8	.710	.696	.91	.86	.05
November 18	1 48	.790	58.9	.711	.697	.91	.86	+0.05
Mean								+0.07

Determination of freezing point of standard Troughton and Simms No. 230.

Date.	Time of observation.	Reading.	Correction.
1873.	*h. m.*	°	°
November 17	11 02	31.91	+0.09
November 17	11 10	31.92	+0.08
November 17	11 17	31.92	+0.08
November 17	2 00	32.00	.00
November 17	2 30	.00	.00
November 17		.00	.00
November 18	11 10	32.00	.00
November 18		.00	.00
November 18		.00	.00
November 18	12 35	32.00	.00
November 18		.00	.00
November 18		.00	.00
November 18	2 30	32.00	.00
November 18		.00	.00
November 18		.00	+0.00
Mean			+0.02

In the corrections found at Kew observatory to this standard, the correction at freezing point was 0.0, and at boiling point + 0.1. The difference of the corrections at freezing and boiling point, as seen from the foregoing result, is + 0.05.

The freezing point of this standard was tested again December 19 and 20. Three determinations were made on each day. After each determination, the thermometer was taken from the ice and repacked before another determination was made. On January 6, 1874, the freezing point was also tested; four determinations were made, the thermometer being repacked in different ice after each determination, the same as on December 19 and 20.

Determination of freezing point of standard Troughton and Simms No. 230.

Date.	Time of observation.	Reading.	Correction.	Date.	Time of observation.	Reading.	Correction.
	h. m.	°	°		h. m.	°	°
December 19, 1873...	10 50	32.05	−0.05	January 6, 1873.....	10 05	32.07	−0.07
December 19, 1873....	12 06	.06	.06	January 6, 1873.....	10 34	.06	.06
December 19, 1873....	3 00	.08	.08	January 6, 1873.....	11 10	.07	.07
December 20, 1873....	2 45	.08	.08	January 6, 1873.....	11 36	.07	−0.07
December 20, 1873....	3 20	.06	.06				
December 20, 1872...	4 00	.05	−0.05				
Mean			−0.06	Mean			−0.07

The corrections to standard Troughton and Simms No. 230 can be found at any time by applying a constant difference equal to the correction at freezing point at that time to the corrections found at Kew observatory.

Before the boiling point of the thermometer was determined, the correction at freezing point was −0.16 of a degree. In all comparisons made between this standard and other thermometers previous to October 15, the corrections to be used are found by applying −0.16 of a degree to the original corrections. In all comparisons made between December 19 and January 6 the corrections to be used are found by applying −0°.07.

The boiling and freezing points of standard Würdemann and old standard Troughton and Simms have also been determined.

Both of these standards are brass-scale thermometers. Standard Würdemann has two systems of graduation, Fahrenheit and Centigrade. The graduation extends from −20° to +220° Fahrenheit. The length of the brass scale is 18.1 inches. The bulb is spherical, its diameter being about 0.75 of an inch. Old standard Troughton and Simms also has two systems of graduation, Fahrenheit and Réaumur. The graduation extends from −20° to +220° Fahrenheit. The Fahrenheit scale is graduated to half-degrees. The graduation of the half-degrees is very inaccurate. In many instances, the difference in length of successive half-divisions is very marked. The bulb of this thermometer is spherical and has a diameter of about 0.6 of an inch.

For the purpose of testing these thermometers, the tubes were taken from the brass scales. The graduations around the boiling and freezing point were transferred from the brass scales to slips of paper. These slips of paper were pasted on the glass tubes, so that corresponding graduations were coincident with the scratches on the glass tube, marking boiling and freezing points.

In the determinations of freezing point made August 18, 19, and September 11, the readings were made with a telescope, and the fractional part of the degree estimated.

Determination of freezing point of standard Würdemann and Old Standard Troughton and Simms.

Date.	Standard Würdemann.		Old Standard Troughton and Simms.	
	Reading.	Correction.	Reading.	Correction.
	°	°	°	°
August 18, 1873	32.00	0.00	.....	.....
August 19, 1873	32.00	.00	.....	.....
September 11, 1873	32.00	.00	32.05	−0.05

In the determinations of boiling point of these two standards, made October 17, 18, 20, 22, 23, 24, and 25, the readings were made with a telescope, and the fractional part of the degree estimated.

Determination of boiling point of standard Würdemann.

Date.	Time of observation.	Mean of barometer-readings.	Mean of attached thermometer readings.	Barometer reduced to 32° Fahrenheit.	Barometer at sea-level.	Boiling point.	Observed boiling point.	Correction.
	h. m.	*in.*	°	*in.*	*in.*	°	°	
October 17, 1873	11 34	29.620	70.2	29.510	29.496	211.[illegible]8	210.[illegible]9	+0.[illegible]
October 17, 1873	12 33	.580	68.5	.474	.460	211.92	210.76	.[illegible]
October 17, 1873	3 28	.503	67.0	.402	.388	211.10	210.58	.[illegible]
October 17, 1873	4 32	.484	67.5	.382	.368	211.06	210.48	.[illegible]
October 18, 1873	11 17	.302	65.8	.205	.191	210.76	210.21	.[illegible]
October 18, 1873	12 00	.316	66.8	.215	.201	210.78	210.25	.[illegible]
October 20, 1873	11 22	.448	56.1	.375	.361	211.05	210.51	.[illegible]
October 20, 1873	12 22	.419	56.0	.347	.333	211.01	210.39	.[illegible]
October 20, 1873	4 24	.324	51.4	.263	.249	210.86	210.23	.[illegible]
October 22, 1873	3 14	.273	58.2	.196	.182	210.75	210.12	.[illegible]
October 22, 1873	4 00	.269	57.8	.192	.178	210.74	210.12	+0.[illegible]
Mean								−0.[illegible]

Determination of boiling point of Old Standard Troughton and Simms.

Date.	Time of observation.	Mean of barometer-readings.	Mean of attached thermometer readings.	Barometer reduced to 32° Fahrenheit.	Barometer at sea-level.	Boiling point.	Observed boiling point.	Correction.
	h. m.	*in.*	°	*in.*	*in.*	°	°	
October 23, 1873	3 11	29.586	62.9	29.495	29.481	211.26	212.80	−1.54
October 24, 1873	11 07	.812	57.4	.734	.720	.66	213.00	.34
October 24, 1873	12 00	.798	60.3	.713	.699	.63	212.97	.34
October 24, 1873	2 48	.761	59.8	.677	.663	.57	212.97	.[illegible]
October 24, 1873	3 43	.764	59.5	.680	.666	.57	212.97	.[illegible]
October 25, 1873	10 45	.836	53.7	.767	.753	.72	213.04	.32
October 25, 1873	11 35	.830	57.3	.753	.739	.69	213.05	−1.[illegible]
Mean								−1.[illegible]

On November 11, 12, and 13 the boiling point of standard Würdemann was again tested, and immediately after each determination of boiling point the freezing point was tested.

Determination of boiling point of standard Würdemann.

Date.	Time of observation.	Mean of barometer-readings.	Mean of attached thermometer readings.	Barometer reduced to 32° Fahrenheit.	Barometer at sea-level.	Boiling point.	Observed boiling point.	Correction.
	h. m.	*in.*	°	*in.*	*in.*	°	°	
November 11, 1873	11 58	29.230	64.9	29.135	29.121	210.64	210.06	−0.[illegible]
November 11, 1873	3 58	.018	61.9	28.931	28.917	210.29	209.70	.[illegible]
November 12, 1873	8 52	.028	56.1	.957	.943	210.34	209.75	.[illegible]
November 12, 1873	8 58	.030	57.0	.956	.942	.33	.75	.[illegible]
November 12, 1873	9 06	.038	58.6	.960	.946	.34	.74	.[illegible]
November 12, 1873	12 26	.130	62.8	29.041	29.027	210.48	210.03	.[illegible]
November 12, 1873	12 35	.136	63.6	.045	.031	.49	209.99	.[illegible]
November 12, 1873	12 43	.141	63.9	.049	.035	.49	209.98	.[illegible]
November 13, 1873	10 40	.320	53.3	.255	.241	210.85	210.30	.[illegible]
November 13, 1873	10 48	.324	53.6	.259	.245	.85	.30	.[illegible]
November 13, 1873	10 56	.324	53.8	.258	.244	.85	.31	.[illegible]
November 13, 1873	1 23	.306	55.3	.236	.222	210.81	210.30	.[illegible]
November 13, 1873	1 30	.307	55.4	.237	.223	.82	.30	.[illegible]
November 13, 1873	1 39	.309	55.0	.240	.226	.82	.31	+0.[illegible]
Mean								−0.[illegible]

In these determinations of boiling and freezing points, the fractional part of the degree was determined with micrometer.

Determination of freezing point of standard Würdemann.

Date.	Time of observation.	Reading.	Correction.
	h. m.	°	°
November 11, 1873	1 00	31.43	+0.57
November 11, 1873	4 54	31.43	.57
November 12, 1873	10 00	31.36	.64
November 12, 1873	10 31	31.37	.63
November 12, 1873	2 23	31.42	.58
November 12, 1873	2 36	31.42	.58
November 12, 1873	3 06	31.49	.51
November 13, 1873	11 49	31.45	.55
November 13, 1873	12 06	31.38	.62
November 13, 1873	2 38	31.42	.58
November 13, 1873	2 56	31.45	.55
November 13, 1873	3 07	31.43	+0.57
Mean			+0.58

The freezing point of this standard was also tested on December 19, 20, 1873, and January 6, 1874. The fractional part of the degree was determined by micrometer.

Determination of freezing point of standard Würdemann.

Date.	Time of observation.	Reading.	Correction.
	h. m.	°	°
December 19, 1873	10 50	31.63	+0.37
December 19, 1873	12 06	.62	.38
December 19, 1873	3 00	.65	.35
December 20, 1873	2 45	.66	.34
December 20, 1873	3 20	.65	.35
December 20, 1873	4 00	.65	+0.35
Mean			+0.36
January 6, 1873	10 05	31.70	+0.30
January 6, 1873	10 34	.66	.34
January 6, 1873	11 10	.65	.35
January 6, 1873	11 36	.64	.36
Mean			+0.34

Comparisons were made between standard Troughton and Simms No. 230, standard Würdemann, Old Standard Troughton and Simms, and a number of brass and ivory scale thermometers at various points between 40° and 90° Fahrenheit.

When comparisons were made, the various thermometers to be compared were suspended vertically in a glass vessel filled with water, their bulbs being nearly in the same horizontal plane. During a set of comparisons, the air was maintained at a temperature as nearly as possible equal to that of the water in the vessel. The water was stirred continually for at least half an hour before any readings of the thermometers were made. Four sets of readings were usually made, the mean of which constituted a comparison. In the comparisons of standard No. 230 with the other standards, about fifty such comparisons were made between 40° and 90°. In the comparisons of standard thermometers, the readings were made with a telescope of short focus, the line of sight being arranged horizontally. The telescope had a magnifying-power of 35. The fractional part of the degree was estimated. Care was taken to have the glass surface of the vessel through which the readings were made perpendicular.

The comparisons of standard thermometers were made before the boiling points were determined, and when the correction to standard No. 230 at 32° was —0.16 of a degree, and the correction to standard Würdemann to reduce to the mark on the glass was 0.00. When the tube of standard Würdemann is attached to the brass scale, the mark on the glass tube at freezing point is 0.10 of a degree above graduation 32° of brass scale, the temperature of the scale and tube being about 60° F. Owing to the difference in expansion of brass and glass, when the temperature of the tube and scale is 32° F. the mark on the glass tube would be 0.07 above graduation 32° on the brass scale. On account of the proximity of graduation 212° and the point where the tube is fastened to the scale, the relative position of the mark at boiling point and graduation 212° would be affected only slightly by changes of temperature.

Corrections to standard Würdemann.

True temperature.	Correction.	True temperature.	Correction.
°	°	°	°
32	— 0.07	65	— 0.4
40	— 0.04	70	— 0.5
45	— 0.13	75	— 0.4
50	— 0.27	80	— 0.5
55	— 0.35	85	— 0.4
60	— 0.40	90	— 0.3

Boiling changes the freezing point of thermometers, so that the corrections to standard Würdemann, after the boiling point was tested, would differ from the foregoing by a constant quantity, depending on the amount by which the freezing point was changed. On January 6, 1874, the correction to this standard at freezing point to reduce to scratch on glass tube was +0.34. The corrections to the thermometer after that date, until a further determination of its freezing point is made, will, therefore, be the corrections in the foregoing table, with the constant difference +0.34 of a degree applied.

Old standard Troughton and Simms has been rejected on account of the large errors in graduation and the large correction at boiling point.

Several brass-scale thermometers were compared with standard No. 230. Nos. 2, 3, 4, 5, 6, 10, 11, and 12 are primary base apparatus thermometers. The temperature of the air during these comparisons was nearly the same as that of the water in the vessel. The readings were made to tenths of a degree without the assistance of a telescope.

The freezing points of these thermometers were tested after the comparisons were made.

Corrections to be applied to scale-readings.

True temperature.	2	3	4	5	6	10	11	12	1428	1439	1444	146
°	°	°	°	°	°	°	°	°	°	°	°	°
32	—0.8	—1.3	—1.0	.....	0.0	—0.7	—0.8	—0.6	—0.6	—0.7	—0.6	—0.7
42	—0.9	—1.4	—1.2	.....	—0.2	—0.7	—0.8	—0.7	—0.7	—0.7	—0.7	—0.7
52	—1.3	—1.8	—1.5	.....	—0.6	—0.9	—1.1	—1.0	—0.9	—1.0	—1.0	—1.0
62	—1.8	—1.9	—1.7	.....	—0.9	—1.0	—1.1	—1.1	—1.1	—1.0	—1.1	—1.1
73	—1.8	—2.1	—1.7	—0.1	—1.0	—1.1	.....	.....	.....	.....	.....	.....
78	—1.9	—2.1	—1.7	—0.1	—1.0	—1.0	.....	.....	.....	.....	.....	.....
81	—2.0	—2.2	—1.8	—0.1	—1.0	—1.1	.....	.....	.....	.....	.....	.....
84	—2.0	—2.3	—1.8	—0.1	—1.0	—1.1	.....	.....	.....	.....	.....	.....

The comparisons of brass-scale thermometers with standard No. 230 between 42° and 62° inclusive were made in January, 1874, when the correction to standard at freezing point was —0.07 of a degree. The remainder of the comparisons were made in June, 1873, when the correction to the standard at freezing point was —0.16. Secondary base apparatus thermometers 5, 6, W, X, Y, Z, were compared with standard No. 230 on January 6 and 7, 1874.

These are ivory-scale thermometers. Their freezing points were determined before the comparisons were made. In comparing the thermometers, they were put in the glass vessel containing water at a temperature of 100° F., the temperature of the room being about 60°.

Readings were made from time to time as the temperature of the water was falling. When the temperature of the water was nearly that of the air, a quantity of ice was put in the vessel, and after it had all melted and the water had been thoroughly stirred, readings were again made; the temperature of the water was brought down again by means of ice, and readings made as before. When the water was brought below 60°, the temperature of the room was allowed to fall, so that there should be as little difference as possible between the temperature of the air and the water.

Corrections to be applied to scale-readings.

True temperature.	5	6	W	X	Y	Z
°	°	°	°	°	°	°
32.0	+ 0.6	− 4.0	+ 4.4	− 0.1	+ 3.0	+ 2.4
38.4	+ 0.4	− 3.6	+ 4.4	0.0	.....	+ 3.2
49.3	.....	− 2.7	+ 3.6	+ 0.5	+ 2.3	+ 2.1
59.3	+ 0.3	− 1.9	+ 2.7	+ 0.5	+ 1.3	+ 1.1
70.1	+ 0.1	− 1.5	+ 1.1	+ 0.5	+ 0.3	+ 0.1
77.0	0.0	− 0.8	+ 1.0	+ 1.0	+ 0.4	− 0.8
82.8	− 0.2	− 0.6	+ 0.8	+ 1.0	0.0	− 1.2
87.1	− 0.6	− 0.5	− 0.3	+ 1.1	− 0.7	− 1.9
91.0	− 0.5	+ 0.5	− 0.1	+ 1.3	− 0.5	.....
95.3	− 0.6	+ 0.3	− 0.6	+ 1.3	− 0.8	.....
100.0	− 0.9	+ 0.7	− 0.0	+ 1.0	− 0.5	− 1.7

Two ivory-scale thermometers were compared with standard No. 230 at the same time that comparisons were being made between standard Würdemann, Old Standard Troughton and Simms, and standard No. 230.

Before any comparisons were made between these thermometers and the standard, marks were made on the ivory scales which would show in the future any change in the relative positions of the glass tube and scale. In December, 1873, when additional comparisons were being made with the standard, it was found that a change had taken place. It was also found that when the thermometers were put in water the ivory scale expanded about 0.004. This expansion, owing to the manner in which the tube was fastened to the scale, would cause the thermometer when in water to read greater than when dry and in the air.

For 3170 A the reading would be 0°.36 greater at 32°, and 0°.17 greater at 90°.

For 3171 B the reading would be 0°.32 greater at 32°, and 0°.13 greater at 90°.

The following are the corrections when the thermometers are dry, and when the top of the brass fixture retaining the thermometer tube is tangent to the scratch on the ivory scale:

Corrections to be applied to the scale-readings to reduced to true temperature.

True temperature.	3170 A	3171 B
°		
32	+ 0.5	+ 0.8
40	+ 0.49	+ 0.62
45	+ 0.33	+ 0.48
50	+ 0.14	+ 0.34
55	− 0.01	+ 0.24
60	− 0.14	+ 0.17
65	− 0.18	+ 0.13
70	− 0.23	+ 0.08
75	− 0.23	+ 0.03
80	− 0.22	− 0.03
85	− 0.21	− 0.02
90	− 0.25	− 0.06

Very respectfully, your obedient servant,

T. RUSSEL,
Assistant Engineer.

Maj. C. B. COMSTOCK,
Corps of Engineers, Bvt. Brig. Genl., U. S. A.

APPENDIX H.—COMPARISON OF LAKE SURVEY STANDARD YARDS NOS. 6, 7, 8, 9, AND 10.

Report of Mr. E. S. Wheeler, Assistant Engineer.

OFFICE UNITED STATES LAKE SURVEY.
Detroit, Mich., March 12, 1874.

SIR: I have the honor to report the following results of the comparison of the Lake Survey standard yards Nos. 6, 7, 8, 9, and 10 with each other.

These comparisons were made in the cellar of the Lake Survey office during January, February, and a part of March, 1874. Two comparators were mounted upon a beam of wood one yard apart. Their quills were lined and leveled in the usual manner. Two Y's were mounted between the comparators, so that when a yard rested in them the contact of the quills with the ends of the yards was central. Two yards were placed side by side, and wrapped with seven thicknesses of woolen cloth; they were then suspended together by spiral springs, so that only four ounces of their weight was borne by the Y's. Both yards and comparators were then covered with a wooden box, having glass windows in the top. The milled head of the micrometer-screw in the Würdemann comparator projected through one end of the box, so that it could be turned from the outside. The yards were lifted in and out of the Y's by taking hold of the spiral springs above the box. Two thermometers were placed inside the box, so that they could be read through the glass windows. The corrected readings of these thermometers are taken for the temperature of the yards. A maximum and a minimum thermometer were placed on the outside of the box and read daily.

The observations were made as follows: The yard nearest the observer was placed in the Y's first. The bubble in the level of the Stackpole comparator was then made to play by moving the yard longitudinally. This was easily done by taking hold of the spiral springs above the box and pressing them lightly to the right or left. The bubble in the Würdemann comparator was then made to play by turning the micrometer-screw.

The micrometer and level of the Würdemann and the level only of the Stackpole comparator were then read. The yards were then alternated in the Y's, and the readings repeated. This was done eleven times, which gives, by comparing the reading of one yard with the mean reading of the other before and after, five results. The average time occupied in taking a set of five was twenty-two minutes. After an absence of one or two hours, the observer would return and take another set. In this way the ten probable combinations of twos were observed. After each pair had been observed on at least two days, the comparators were taken out, lined, leveled, and centered a second time, and the entire series of observations repeated, taking care to change sides with the yards, so that the yard which was nearest the observer in the first series should be farthest from him in the last, thus eliminating the error caused by the heat of the observer's body. The results are tabulated below. The unit is one-millionth of an inch of the Würdemann comparator.

Pair of yards used.	Number of days.	Number of observations.	Mean of observations.	Mean of daily means.	Mean of A. M.'s.	Mean of P. M.'s.	Long yard nearest.	Short yard nearest.	Highest temperature.	Lowest temperature.	Mean temperature.	Maximum of room.	Minimum of room.
									°	°	°	°	°
(7)-(6)	9	93	1334	1334	1335	1331	1337	1329	41.5	37.0	38.4	41.5	37.0
(8)-(6)	5	45	99	95	101	89	100	94	39.2	37.1	38.4	40.0	37.1
(5)-(9)	7	72	1478	1473	1470	1483	1485	1464	40.0	38.4	39.1	40.8	38.1
(10)-(6)	4	46	1585	1586	1584	1588	1595	1577	41.8	38.8	40.4	41.8	38.9
(7)-(8)	4	55	1239	1238	1238	1238	1235	1241	41.4	38.5	39.7	41.4	38.5
(7)-(9)	4	45	2825	2823	2826	2820	2811	2836	40.1	38.0	38.8	40.1	37.8
(10)-(7)	4	37	234	235	236	231	240	229	40.3	38.3	39.6	40.3	37.5
(8)-(9)	4	42	1585	1585	1584	1586	1593	1579	41.3	37.9	39.9	42.0	37.8
(10)-(8)	3	40	1493	1491	1487	1494	1499	1487	41.2	37.4	40.1	42.1	37.2
(10)-(9)	4	42	3062	3064	3066	3053	3087	3042	41.2	37.1	38.8	42.1	37.0
Totals	48	517	14934	14924	14927	14913	14982	14878	.....	.....	39.3	.....	.....

In the preceding table, the tenth, eleventh, and twelfth columns contain the highest lowest, and mean temperatures of the yards when they were observed. The thirteenth and fourteenth columns contain the highest and lowest temperatures of the room as shown by the maximum and minimum thermometers during the whole number of days observations were made on that pair.

The table also shows:

1st. The mean of all the results, the mean of the daily means, the mean of the A. M.'s and the mean of the P. M.'s are all practically the same.

2d. The heat of the observer's body makes the yard which is nearest him 0.000005 inch longer than the other one.

3d. The entire range of temperature in the room during comparisons, from January 14 to March 9, 1874, was 5°.

Taking the means of the daily means, and correcting them to British inches, and then forming the equations of condition, we shall have the following—

Equations of condition.

	Residuals.
(7) − (6) − 1339 = 0	7
(8) − (6) − 99 = 0	1
(6) − (9) − 1479 = 0	7
(10) − (6) − 1592 = 0	2
(7) − (8) − 1243 = 0	5
(7) − (9) − 2834 = 0	2
(10) − (7) − 236 = 0	8
(8) − (9) − 1591 = 0	7
(10) − (8) − 1497 = 0	5
(10) − (9) − 3076 = 0	0

Equal weights are assigned to all the equations of condition. Though some have more results than others, they do not, probably, have greater weight, for the additional results were taken because the usual number did not, owing to change of temperature, &c., seem to have the usual weight.

The normal equations will then be as follows:

$$4(7) - (8) - (9) - (10) = (6) + 5180$$
$$4(8) - (7) - (9) - (10) = (6) - 1060$$
$$4(9) - (7) - (8) - (10) = (6) - 8980$$
$$4(10) - (7) - (8) - (9) = (6) - 6401$$

Solving, we find—

$$(7) = (6) + 1346$$
$$(8) = (6) + 98$$
$$(9) = (6) - 1486$$
$$(10) = (6) + 1590$$

Substituting these values in the equations of conditions, the residuals there given are found. Solving for probable error, it is found to be 0.000002 inch for all the quantities

Collecting the temperatures, we find that—

(6) − (7) at 39°.2 = − 1346 British inches.
(6) − (8) at 39°.3 = − 98 British inches.
(6) − (9) at 39°.5 = + 1486 British inches.
(6) − (10) at 39°.5 = − 1590 British inches.

Very respectfully,

E. S. WHEELER,
Assistant Engineer.

General C. B. COMSTOCK,
Superintendent United States Lake Survey.

NOTE.—The Würdemann values are multiplied by 1.0038 to reduce them to British inches.

APPENDIX I.—COMPARISONS OF STANDARD 15-FOOT BAR WITH NEW LAKE SURVEY YARDS NOS. 6, 7, 8, 9, AND 10.

1.—*Report of Mr. E. S. Wheeler, Assistant Engineer.*

OFFICE UNITED STATES LAKE SURVEY,
Detroit, Mich., June 16, 1873.

SIR: I have the honor to report the following results of the comparisons of the standard 15-foot bar with the new yards numbered 6, 7, 8, 9, and 10.

The comparisons were begun in February, 1872, and stopped in May. The bar was used during the summer in comparisons with the tubes at Fond du Lac, Wis.

Additional comparisons have been made during the present month.

The bar and yards were placed parallel to each other and two inches apart in a wooden box. The yards rested in adjustable Y's, and were supported by spiral springs hanging from the ceiling above. These springs are fastened to each yard nine inches from the end, and are so adjusted that the yards press in each Y with a weight of only four ounces.

The spiral springs are inclined toward the center of the box at such an angle that the yards press against each other longitudinally with a force of one pound, (making the pressure at the ends of the middle one two pounds less the friction in the Y's.)

The bar is supported on small rollers 18 inches apart, and has on each side guides furnished with set-screws, to facilitate lining.

The box containing the yards is about 8 inches wide and 3 inches deep; the sides and bottom are double, and packed with cotton. The top is single; the ends are closed with tin, which has small holes through which the ends of the bar and yards project about one-fourth of an inch; they are also packed with cotton. During all the comparisons made in 1873 there were four heavy bed quilts wrapped around the outside of the box; three thermometers were in the box, one at each end and one in the middle. They were read and corrected in the usual manner.

The bar was lined with a fine silver wire, and leveled with a hand-level, whose supports were 18 inches apart. For lining the yards, a half-cylinder of brass, with a diameter the same as that of the axis of the yards, was prepared. On its plane surface diagonal lines were drawn, so that their intersection was in the middle. The silver wire was stretched over the Y's, and the half-cylinder laid in the Y's, which were then adjusted till the intersection of the lines on the half-cylinder was directly under the wire. The yards were leveled by fastening a level to one of the yards and reversing it in the Y's. A small level was prepared for those Y's, which were only two inches apart.

The accuracy of the line and level of the yards was tested by coating the ends of the yards with wax, then bringing them in contact and examining the point of contact, which showed, as a litte round point, where the wax was pushed away. This point was in every case precisely in the center of the end of the yard.

The comparators were the Würdemann and Stackpole; they were mounted on the piers in the basement of this office in the usual manner.

The Würdemann was read; the level only of the Stackpole was used.

Before observations made at widely varying temperatures can be compared with each other, it is necessary to know the difference in the rates of expansion of the bar and yards. This was found from the observations themselves.

The observations were selected in the following way: The curves for the bar, yards, and temperature for each day were plotted. If they passed through a maximum or minimum, the day's work was used; if they did not, the day's work was rejected.

The difference between the lengths of the bar and yards at the maximum or minimum was taken as the result for the day, and the day's work treated as a single observation. The curves for some days were much more perfect than others. Sometimes the curves passed rapidly through the change; at others they were almost stationary for six or seven hours. Different weights were therefore assigned different days' work. These weights are arbitrary, being made simply from an inspection of the curves. They range from one to ten.

The following is a list of the days used, with their curves, and the weights assigned them:

Date.	Temp.	Bar longer than yards, Würdemann comparator inch.	Weight.	
February 26, 1872	36.8	0.00821 inch	1	Minimum.
March 5, 1872	24.7	0.00791 inch	5	Do.
March 11, 1872	33.9	0.00823 inch	1	Do.
March 14, 1872	37.1	0.00811 inch	1	Maximum.
March 19, 1872	36.6	0.00815 inch	1	Minimum.
April 26, 1872	61.7	0.00833 inch	6	Maximum.
May 1, 1872	61.4	0.00852 inch	6	Do.
May 4, 1872	49.3	0.00820 inch	6	Minimum.
May 10, 1872	63.4	0.00830 inch	5	Do.
May 13, 1872	56.7	0.00837 inch	3	Maximum.
June 6, 1873	68.9	0.00858 inch	4	Do.
June 11, 1873	67.7	0.00844 inch	8	Do.
June 12, 1873	66.8	0.00847 inch	8	Minimum.
June 13, 1873	64.7	0.00847 inch	4	Do.
June 17, 1873	68.1	0.00848 inch	4	Do.
June 20, 1873	71.5	0.00849 inch	8	Do.
June 24, 1873	71.3	0.00846 inch	8	Rising.

During the observations of 1872, a pointed quill was used in the Würdemann comparator, and a blunt one in the Stackpole comparator. In 1873, pointed quills were used in both comparators.

An examination was made to see if there was any difference in the results obtained with a pointed or blunt quill. The two quills were used alternately in the Stackpole comparator for two days. The mean results obtained with the pointed quill differed only 0.000006 inch from those obtained with the blunt quill—a quantity so much less than the errors of observation that it may be entirely neglected; there is, therefore, no correction on this account to be made to the observations of 1872.

The blunt and pointed quills were also alternated in the Würdemann comparator. It was found that the blunt quill made the difference between the bar and yards 0.00015 greater than the pointed quill. This is partly because the end-surface of the bar is not at right angles to the axis of the bar, and partly because the quill of the comparator as then mounted was not in line with the bar, so that the contact of the bar and quill was not central; but since the pointed quill was used in this comparator during all the time, this difference does not enter into the observations at all, and need not, therefore, be considered.*

The inclinations of the end-surfaces of the bar were examined. The quill at one end of the bar was kept in contact with the middle of the bar, while the quill at the opposite end was read one-tenth of an inch to the right, left, above, and below the center.

The difference in these observations give the data for computing the angular position of the plane surfaces at the ends of the bar.

The ends of the bar approximate quite closely to a plane surface, but are not quite perpendicular to the axis of the bar. The greatest deviation found being 15′ at the marked end of the bar, an error of one-fiftieth of an inch in centering the pointed quill may make an error of 0.00010 in the reading of the comparator; but this error will be sometimes plus and sometimes minus, so that in a large number of readings it will be eliminated. It is probably due to this cause that slight irregularities in the curve of the bar are greater than in that of the yards.

The ends of the pointed quills have a radius of about one twenty-fifth of an inch. The inclination of the end-surfaces of the bar to the axis of this pointed quill and bar will make a constant error, arising from the point of contact not being central, which, in the case of the maximum angle, (15′,) will be 0.000004. This error is constant and should be subtracted from the readings of the bar.

Very respectfully, your obedient servant,

E. S. WHEELER,
Assistant Engineer.

General C. B. COMSTOCK.

2.—*Report of Mr. R. S. Woodward, Assistant Engineer.*

Determination by least squares of the difference between the standard bar and Lake Survey yards Nos. 6, 7, 8, 9, and 10, at 62° Fah., and also the difference between their co-efficients of expansion, resulting from the data in the preceding report.

The data from which the within computation is made were obtained from MS. report No. 203.

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*Provided the inclination of the quill to axis of bar is so small as not to affect 0.00839 inch, or not exceeding 2° 30′. It is scarcely possible that its error can have been so great.—C. B. C.

In the formation of the normal equations, the co-efficients were checked by means of the usual "control."

The weights of the quantities sought were determined by two different methods and found to agree.

The Bar being longer than the Yards, and the value of the difference between their co-efficients of expansion being positive, (*i. e.*, $e = +1.177$,) (*i. e.*, bar expands that much faster,) it appears that the Bar expands or contracts faster than the Yards.

Throughout the computation, 0.00001 inch has been used as the unit, the observed difference (D t°) being expressed in the same.

Hence the values of the quantities sought, and their probable errors, are also expressed in terms of the same unit.

R. S. WOODWARD.

JANUARY, 1874.

D 62° = difference between Bar and Yards at 62° F.
D t° = difference between Bar and Yards at t° F.
e = difference between the co-efficients of expansion of the bar and yards.

Hence the equation of condition—

$$D\,62^\circ + (t^\circ - 62^\circ)\,e - Dt^\circ = 0$$

t°	$(t^\circ - 62^\circ)$	D t°	Equations.	Wt.	v	v v
36.8	−25.2	821	D 62−25.2 e−821=0	1	−11.23	126.1129
24.7	−37.3	791	D 62−37.3 −791=0	5	+10.12	102.4144
33.9	−28.1	823	D 62−28.1 −823=0	1	−16.65	277.2225
37.1	−24.9	811	D 62−24.9 −811=0	1	−00.88	000.7744
36.6	−25.4	815	D 62−25.4 −815=0	1	−05.47	29.9209
61.7	−00.3	833	D 62−00.3 −833=0	6	+14.87	219.1168
61.4	−00.6	852	D 62−00.6 −852=0	6	−32.55	1059.5025
49.3	−12.7	820	D 62−12.7 −820=0	6	+10.96	120.1216
63.4	+01.4	830	D 62+01.4 −830=0	5	+24.75	612.5625
56.7	−05.3	837	D 62−05.3 −837=0	3	−06.61	43.6921
68.9	+06.9	858	D 62+06.9 −858=0	4	−20.92	437.6464
67.7	+05.7	844	D 62+05.7 −844=0	8	+06.02	36.2404
66.8	+04.8	847	D 62+04.8 −847=0	8	−05.46	29.8116
64.7	+02.7	847	D 62+02.7 −847=0	4	−09.81	96.2361
68.1	+06.1	848	D 62+06.1 −848=0	4	−02.80	07.8400
71.5	+09.5	849	D 62+09.5 −849=0	8	+04.53	20.5209
71.3	+09.3	846	D 62+09.3 −846=0	8	+12.34	151.6756
			[v v]			=3371.5817
			$\frac{1}{15}$ [v v]			= 224.7666

Normal equations.

$$79.0\,D\,62^\circ - 83.4\,e - 66216.0 = 0$$
$$-83.4\,D\,62^\circ + 12937.4\,e + 54783.8 = 0$$

$D62^\circ = 839.42$
$e = +1.177$
Wt. of $D62^\circ = 78.46$
Wt. of $e = 12849.35$

Mean error of $Dt = 14.99$
Probable error of $Dt = 10.11$
Probable error of $D62^\circ = 01.711$
Probable error of $e = 00.134$

APPENDIX J.—INSTRUMENTAL CONSTANTS OF TROUGHTON AND SIMMS'S NON-REPEATING THEODOLITE.

Report of Mr. G. Y. Wisner, Assistant Engineer.

OFFICE UNITED STATES LAKE-SURVEY,
Detroit, Mich., December 20, 1873.

GENERAL: I have the honor to submit the following report upon the determination of the instrumental constants of the Lake-Survey Troughton and Simms's non-repeating theodolite. The instrument has a 14-inch horizontal circle, reading with three micrometers to single seconds, and a 12-inch vertical circle, reading with two verniers to ten seconds. The horizontal circle is divided to 5′, and the vertical to 10′. Were the verti-

cal circle provided with micrometers instead of verniers, it would be of much greater value where accuracy is required in the measurement of vertical angles.

The telescope is 24.5 inches focal length, with an object-glass 2.24 inches in diameter, and is provided with an illuminated axis. The value of one division of the striding-level was found to change with temperature, owing to the glass bulb being too firmly set in the brass case. Values have been determined at different temperatures, varying from 14° to 70°, from which the annexed curve was plotted. The curve indicates that the value of one division increases uniformly with the temperature. The values were observed on different parts of the graduation, and are apparently uniform throughout whole length.

The telescope was revolved through 90° of arc, and no change was noted from irregularity of pivots.

The eccentricity was found by reading the micrometers for every ten degrees for whole limb, and reducing by method given by Chavenet. The power of the eye-pieces was determined, in combination with object-glass, with a Ramsden's dynameter.

The values of the equatorial intervals, and of one revolution of micrometer to telescope, were determined by setting on threads of collimator and reading of the corresponding arcs from horizontal limb. Each value is the mean of five determinations. The value of one division of level to vertical circle was obtained from readings on vertical circle, (mean of ten.) The bulb being set in the same manner as that of the striding-level, it will probably change value with temperature. All the notes from which the following tables were formed will be found in note-book S, 581.

Letting A, B, and C be the readings of the three micrometers, and $120°+\beta$, and $240°+\gamma$, the angular distance of micrometers B and C from micrometer A, then—

$$\tfrac{1}{2}(B+C)-A=\tfrac{1}{2}(\gamma+\beta+\tfrac{3}{2}\,\epsilon\sin(Z+P)$$

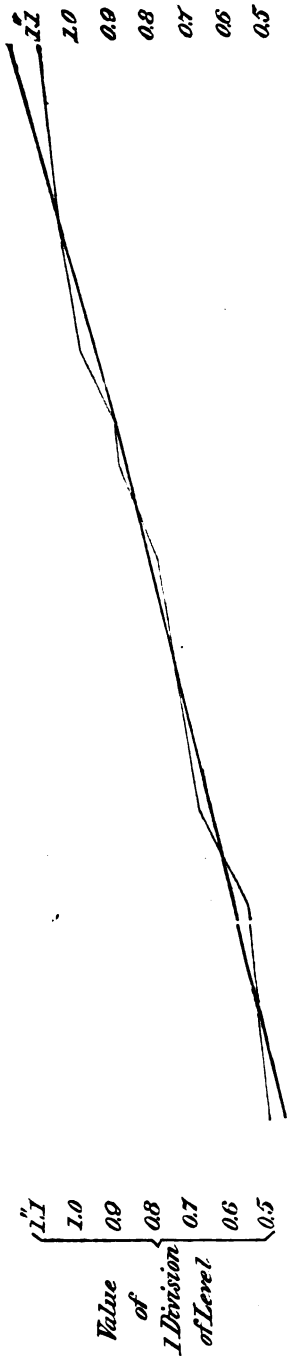
where ϵ is the eccentricity, P the reading of the line passing through center of limb and axis, and Z the division under micrometer A.

$\epsilon = 1''.02$, P = 24° 53′, and $\frac{1}{2}(\gamma+\beta) = -2''.84$

Z	$\frac{1}{2}(B+C)-A$	$\frac{1}{2}(\gamma+\beta)+\frac{3}{2}\epsilon\sin(Z+P)$	Residual.	Z	$\frac{1}{2}(B+C)-A$	$\frac{1}{2}(\gamma+\beta)+\frac{3}{2}\epsilon\sin(Z+P)$	Residual.
00	−2.8	−3.5	0.7	180	−1.4	−2.1	0.7
10	4.2	3.7	0.5	190	0.1	1.9	1.8
20	5.3	4.0	1.3	200	0.8	1.6	0.8
30	5.1	4.1	1.0	210	3.3	1.5	1.8
40	5.4	4.2	1.2	220	4.0	1.4	2.6
50	3.1	4.3	1.2	230	2.4	1.4	1.0
60	4.5	4.3	0.2	240	3.1	1.3	1.8
70	3.8	4.3	0.5	250	2.0	1.3	0.7
80	4.0	4.3	0.3	260	2.3	1.4	0.9
90	2.6	4.2	1.6	270	3.2	1.4	1.4
100	2.8	4.1	1.3	280	2.2	1.5	0.7
110	3.5	3.9	0.4	290	2.2	1.6	0.6
120	2.2	3.7	1.4	300	2.4	1.9	0.5
130	2.4	3.5	1.1	310	2.5	2.1	0.4
140	2.9	3.2	0.3	320	1.6	2.4	0.8
150	2.0	2.9	0.9	330	2.1	2.6	0.5
160	3.0	2.6	0.4	340	2.3	2.9	0.6
170	−2.3	−2.4	0.1	350	−2.5	−3.2	0.7

The following table gives values of constants:

Diameter of horizontal limb	14in.0
Diameter of vertical limb	12in.0
Diameter of object-glass	2in.24
Focal length of telescope	24in.5
Eccentricity of horizontal circle, (toward 24° 53′)	1″.00
Horizontal limb reads to (with three micrometers)	1″.02
Vertical limb reads to (with two verniers)	10″.0
Equatorial interval of wires 1-3 =	7′ 04″.4
Equatorial interval of wires 2-3 =	3′ 32″.4
Equatorial interval of wires 4-3 =	3′ 34″.1
Equatorial interval of wires 5-3 =	7′ 07″.4
One revolution of micrometer to telescope	85″.2
One division of level to vertical circle	3″.1
Pivot correction (illuminated end large)	0″.6
Power of telescope with direct eye-piece (1), diameters	30
Power of telescope with direct eye-piece (2), diameters	46.1
Power of telescope with direct eye-piece (3), diameters	86.2



Power of telescope with diagonal eye-piece, diameters 27.3
Power of magnifiers on vertical circle, diameters 8.8
Power of micrometers to horizontal circle, diameters 40.0

For value of striding level see annexed diagram.

Very respectfully submitted.

GEO. Y. WISNER,
Assistant Engineer.

General C. B. COMSTOCK,
Superintendent United States Lake Survey.

The following curve is that of the values of the striding level (Troughton and Simms's non-repeating theodolite) obtained from observations made at different temperatures. The value at 70 degrees, however, is not very reliable, as the temperature was changing rapidly.

The value at 14 degrees was obtained by comparison with micrometer of zenith telescope No. 19.

That at 25 degrees was determined by comparison with micrometer, and also with striding level (new, 1873) of Troughton and Simms's 42-inch astronomical transit, both agreeing. All the other values are from comparison with striding level of Troughton and Simms's transit.

APPENDIX K.—RESULTS OF METEOROLOGICAL OBSERVATIONS.

Report of Mr. O. B. Wheeler, Assistant Engineer.

OFFICE UNITED STATES LAKE SURVEY,
Detroit, Mich., May 28, 1874.

SIR: I have the honor herewith to submit the results of the reductions of the observations made at the three meteorological stations Port Austin and Monroe, Mich., and Sacket's Harbor, N. Y., for the year 1873.

The tables herewith appended give—

1st. The number of observations of wind from the different points of the compass, and also the total number for months and year.

2d. The resultant direction of the wind for each month and season, and for the year.

3d. The maximum, minimum, and mean barometrical pressure for each month and season, and for the year, reduced to 32° temperature Fahrenheit, but uncorrected for elevation. The barometers remain at the same elevations, respectively, as reported in the Annual Report for 1872.

4th. The maximum, minimum, and mean temperature for each month and season, and for the year.

5th. The mean amount of cloudiness for months, seasons, and the year.

6th. The total amount of rain or melted snow for months, seasons, and the year.

7th. The mean amount of humidity for months, seasons, and the year.

Very respectfully, your obedient servant,

O. B. WHEELER,
Assistant Engineer.

General C. B. COMSTOCK,
Major of Engineers, U. S. A.,
Supt. United States Lake Survey.

PORT AUSTIN, MICHIGAN.

Number of observations of wind from different points of compass, 1873.

Months.	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.	Calms.	No. of observations.
January	6	13	4	9	15	21	7	14	3	92
February	0	5	8	8	8	32	17	6	0	84
March	8	6	1	4	12	25	12	16	4	88
April	8	18	14	8	4	9	12	9	4	86
May	8	24	10	15	4	9	11	6	5	92
June	4	13	14	3	15	13	11	3	10	86
July	6	16	4	3	10	13	13	11	9	85
August	8	29	7	4	22	7	2	7	5	91
September	9	2	7	5	19	23	4	18	2	89
October	10	3	3	11	16	25	6	17	0	91
November	17	5	7	2	11	20	4	21	1	88
December	3	4	2	11	5	31	16	14	5	91
Sum	87	138	81	83	141	228	115	142	48	1,063

MONROE, MICHIGAN.

Number of observations of wind from different points of compass, 1873.

Months.	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.	Calms.	No. of observations.
January	11	9	11	8	14	22	12	6	0	93
February	4	17	3	5	5	21	18	3	0	76
March	5	9	7	5	12	19	21	15	0	93
April	6	25	9	7	5	19	8	11	0	90
May	9	36	6	8	9	16	6	3	0	93
June	4	19	6	12	13	18	7	3	8	90
July	10	17	3	3	9	21	9	6	8	86
August	9	20	6	9	7	16	6	7	13	93
September	13	12	9	6	10	23	5	6	6	90
October	6	12	7	5	13	27	10	8	5	93
November	5	16	7	5	7	22	11	10	7	90
December	4	14	6	5	11	27	15	7	3	92
Sum	86	206	80	78	115	251	128	85	50	1,079

SACKET'S HARBOR, NEW YORK.

Number of observations of wind from different points of compass, 1873.

Months.	N.	N. E.	E.	S. E.	S.	S. W.	W.	N. W.	Calms.	No. of observations.
January	5	21	4	2	17	12	13	7	12	93
February	2	19	1	4	15	12	14	5	12	84
March	3	17	3	3	23	10	19	7	8	93
April	7	27	6	3	6	10	14	6	11	90
May	4	13	2	0	27	13	15	3	15	92
June	1	13	5	3	24	20	11	4	8	89
July	3	8	4	7	25	26	12	1	3	89
August	2	18	11	5	21	11	12	4	3	87
September	3	2	5	7	31	11	19	6	1	85
October	8	14	2	4	29	12	12	9	3	93
November	12	28	9	6	6	10	7	9	3	90
December	5	22	6	1	21	12	14	7	5	93
Sum	55	202	58	45	245	159	162	68	84	1,078

Resultant direction of the wind for each month and season, and for the year 1873.

Months, seasons, and year.	Port Austin.	Monroe.	Sacket's Harbor.
MONTH.			
January	N. 24° W.	S. 40° W.	S. 53° W.
February	S. 56° W.	S. 84° W.	S. 67° W.
March	N. 38° W.	S. 77° W.	S. 5[illegible]° W.
April	N. 3° E.	N. 65° E.	N. 81° W.
May	N. 60° E.	N. 63° E.	S. 36° W.
June	N. 12° W.	S. 38° E.	S. 41° W.
July	N. 46° W.	N. 81° W.	S. 44° W.
August	N. 30° E.	N. 43° E.	S. 26° W.
September	N. 41° W.	S. 28° W.	S. 41° W.
October	N. 26° W.	S. 37° W.	S. 43° W.
November	N. 19° W.	S. 53° W.	N. 78° W.
December	S. 18° W.	S. 37° W.	S. 66° W.
SEASON.			
Spring	N. 10° W.	N. 57° W.	S. 56° W.
Summer	N. 1° W.	N. 81° E.	S. 41° W.
Autumn	N. 28° W.	S. 36° W.	S. 50° W.
Winter of 1872 and 1873	N. 71° W.	S. 69° W.	S. 69° W.
YEAR.			
1873	N. 30° W.	S. 47° W.	S. 52° W.

Maximum, minimum, and mean barometrical pressure for each month and season, and for the year 1873.

Months, seasons, and year.	Port Austin.			Monroe.			Sacket's Harbor.		
	Maximum.	Minimum.	Mean.	Maximum.	Minimum.	Mean.	Maximum.	Minimum.	Mean.
MONTH.									
January	29.747	28.745	29.306	29.776	28.740	29.341	30.182	29.118	29.717
February	29.716	28.722	29.288	29.782	28.843	29.315	30.219	28.985	29.646
March	29.933	28.175	29.265	29.962	28.738	29.297	30.329	28.635	29.597
April	29.643	28.781	29.288	29.503	28.755	29.269	29.933	29.250	29.614
May	29.837	28.882	29.296	29.774	28.912	29.297	30.132	29.119	29.665
June	29.695	28.860	29.301	29.808	28.899	29.334	30.061	29.260	29.657
July	29.577	29.018	29.352	29.619	29.098	29.366	29.923	29.358	29.673
August	29.779	29.115	29.426	29.730	29.137	29.427	30.045	29.515	29.781
September	29.795	28.907	29.369	29.761	29.052	29.411	30.129	29.318	29.719
October	29.870	28.287	29.348	29.759	28.751	29.387	30.249	29.051	29.728
November	29.923	28.724	29.356	29.901	28.703	29.310	30.364	28.816	29.625
December	29.899	28.654	29.412	29.852	28.928	29.445	30.406	29.153	29.772
SEASON.									
Spring	29.933	28.175	29.283	29.962	28.738	29.288	30.329	28.635	29.632
Summer	29.779	28.860	29.360	29.808	28.899	29.376	30.061	29.260	29.704
Autumn	29.923	28.287	29.358	29.901	28.703	29.369	30.364	28.816	29.691
Winter of 1872 and 1873	29.849	28.722	29.412	29.886	28.740	29.372	30.283	28.985	29.708
YEAR.									
1873	29.933	28.175	29.334	29.962	28.703	29.350	30.406	28.635	29.685
Range	1.758			1.259			1.771		

Maximum, minimum, and mean temperature for each month and season, and for the year 1873.

Months, seasons, and year.	Port Austin.			Monroe.			Sacket's Harbor.		
	Maximum.	Minimum.	Mean.	Maximum.	Minimum.	Mean.	Maximum.	Minimum.	Mean.
MONTH.									
January	44	0	18.1	53	—26.5	20.1	51	0	18.2
February	55	7	21.0	58	— 9	25.6	45	0	20.5
March	54	0	29.2	59	— 9	30.6	50	0	27.1
April	61	13	38.7	71	28	43.2	59	20	38.7
May	79	33	51.5	87	34	58.0	82	27	52.8
June	92	34	66.7	96	39	72.5	88	42	64.9
July	90	50	70.9	96	50	74.0	86	42	69.1
August	85	52	70.1	93	52	73.8	83	45	67.4
September	85	40	60.6	91	35	62.7	86	34	60.8
October	78	27	47.6	79	22	47.6	76	21	48.5
November	53	11	31.5	57	4	32.3	54	0	27.5
December	56	14	31.3	57	10	31.4	59	—4	29.0
SEASON.									
Spring	79	0	39.8	87	— 9	43.9	82	0	39.5
Summer	92	34	69.2	96	39	73.4	88	42	67.1
Autumn	85	27	46.9	91	4	47.5	86	0	45.6
Winter of 1872 and 1873	55	—12	19.5	58	—26.5	21.5	51	—42	18.4
YEAR.									
1873	92	—7	44.8	96	—26.5	47.7	88	—4	43.7
Range	99			122.5			92		

Mean amount of cloudiness from 0 *(clear sky) to* 10, *for months, seasons, and year, for the year* 1873.

Stations.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Spring.	Summer.	Autumn.	Winter 1872–1873.	Year.
Port Austin	7.7	3.4	5.9	6.5	3.4	2.9	3.0	2.9	4.2	5.1	7.0	6.9	5.3	2.9	5.4	5.3	4.9
Monroe	7.4	5.0	4.8	5.8	3.8	2.7	3.4	3.1	4.0	4.7	5.7	6.4	4.8	3.1	4.8	5.9	4.7
Sacket's Harbor	8.0	6.3	4.6	7.3	5.3	4.8	5.9	5.7	5.4	6.6	8.6	8.2	5.7	5.5	6.9	7.5	6.4

Total amount of rain or melted snow, in inches, for months, seasons, and year, for the year 1873

Stations.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Spring.	Summer.	Autumn.	Winter 1872–1873.	Year.
Port Austin	3.34	0.24	1.61	5.18	1.89	3.26	1.55	1.31	5.21	6.22	2.76	1.18	8.68	6.12	14.19	5.38	33.75
Monroe	4.37	1.39	3.58	4.17	3.94	3.26	2.22	0.96	2.43	2.03	1.86	4.40	11.69	6.44	6.32	7.62	34.61
Sacket's Harbor	4.50	1.34	6.72	3.44	1.10	1.42	4.18	2.87	2.20	5.30	2.84	2.70	11.26	8.47	10.34	7.96	38.61

Mean amount of humidity for months, seasons, and year, (saturation 1.000,) *for the year* 1873.

Stations.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Spring.	Summer.	Autumn.	Winter 1872–1873.	Year.
Port Austin	.834	.810	.772	.752	.699	.668	.701	.715	.691	.728	.779	.787	.741	.695	.733	.802	.745
Monroe	.785	.727	.672	.702	.690	.670	.691	.677	.676	.713	.689	.765	.688	.679	.693	.750	.705
Sacket's Harbor	.848	.842	.852	.774	.667	.651	.718	.715	.683	.701	.714	.764	.764	.695	.699	.840	.744

APPENDIX L.—CHARTS ISSUED.

Table showing the annual issue of charts of the Northern and Northwestern Lakes.

Prior to October 1, 1857	2,500
October 1, 1857, to October 1, 1858	1,675
October 1, 1858, to October 1, 1859	2,600
October 1, 1859, to October 1, 1860	4,490
October 1, 1860, to October 1, 1861	3,254
October 1, 1861, to October 1, 1862	5,245
October 1, 1862, to October 1, 1863	4,084
October 1, 1863, to October 1, 1864	3,283
October 1, 1864, to October 1, 1865	2,589
October 1, 1865, to October 1, 1866	2,082
July 1, 1866, to July 1, 1867	5,464
July 1, 1867, to July 1, 1868	6,354
July 1, 1868, to July 1, 1869	5,654
July 1, 1869, to July 1, 1870	4,567
July 1, 1870, to July 1, 1871	5,382
July 1, 1871, to July 1, 1872	3,669
July 1, 1872, to July 1, 1873	5,546
July 1, 1873, to July 1, 1874	7,701

List of tracings from original Lake Survey Charts furnished from July 1, 1873, to July 1, 1874.

To whom furnished.	Date.	Locality.
Maj. D. C. Houston	July 26, 1873	Grand Marais Harbor, Lake Superior.
Maj. D. C. Houston	Aug. 21, 1873	Grand Portage Bay, Lake Superior.
William T. Casgrain	Sept. 27, 1873	Vicinity of Sturgeon Bay Canal.
Maj. D. C. Houston	Nov. 3, 1873	Grand Marais Harbor, Lake Superior.
Maj. G. Weitzel	April 9, 1874	Manitou Island, Lake Superior.
Maj. G. Weitzel	April 9, 1874	Huron Islands, Lake Superior.
Maj. G. Weitzel	June 29, 1874	Portion of Siskiwit Bay, Isle Royale, Lake Superior.

APPENDIX DD.

ANNUAL REPORT OF MAJOR G. L. GILLESPIE, CORPS OF ENGINEERS, FOR THE YEAR ENDING JUNE 30, 1874.

SURVEY OF THE BATTLE-FIELDS IN THE SHENANDOAH VALLEY, VIRGINIA.

HEADQUARTERS MILITARY DIVISION OF THE MISSOURI,
OFFICE OF THE CHIEF ENGINEER,
Chicago, Ill., August 25, 1874.

GENERAL: I have the honor to submit herewith my annual report on the survey of the battle-fields in the Shenandoah Valley, for the fiscal year ending June 30, 1874.

The field-work of the surveys in the Shenandoah Valley, with which I was charged by Special Order 46, Headquarters Military Division of the Missouri, May 7, 1873, was completed in October, 1873. My parties were then discharged, retaining one assistant; and in obedience to Special Order No. 78, Headquarters Military Division of the Missouri, September 9, 1873, my office was transferred to Chicago.

In February the topography of the maps was completed, and having received verbal instructions from the Lieutenant-General to indicate upon the maps the positions and principal movements of the contending forces during the engagements, I opened a correspondence with all the accessible commanders of the corps and divisions constituting the Army of the Shenandoah; and with Major Jed. Hotchkiss, late chief engineer on the staff of General Early, commanding the confederate forces in the

Shenandoah Valley, with the view of acquiring more detailed information relative to special movements than was contained in official reports.

While acknowledging a disposition on the part of all from whom I received replies to contribute to the end in view, with but few exceptions the actual information received was meager and unreliable, conflicting in many cases with official reports.

My communications contained a general review of the operations, and were accompanied by accurate sketches of the ground on a suitable scale for ready comprehension, but for reasons which I can only ascribe to lack of memory, or to imperfect comprehension of a topographical sketch, but little available detail was gained. I then deemed it best to print the maps at once, using first only such information as was clearly and unmistakably indicated in the official reports or was gained from other reliable sources, leaving the residue to be added as it could be obtained subsequently.

I desire to express my thanks to Major Hotchkiss, of General Early's staff, for his courtesy in giving locations and movements of the confederate troops.

Early in April an arrangement was entered into with a lithographer in New York City for printing two hundred copies of each of the sheets. Those of Winchester and Waynesborough have been received at this office, and those of Cedar Creek and Fisher's Hill will be received at an early day.

Amount available June 30, 1873	$4,897	71
Amount allotted	2,500	00
	7,397	71
Amount expended	7,383	00
Balance returned to the Treasury	14	71

Respectfully submitted.

G. L. GILLESPIE,
Major of Engineers.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

APPENDIX EE.

ANNUAL REPORT OF MR. CLARENCE KING, GEOLOGIST, FOR THE FISCAL YEAR ENDING JUNE 30, 1874.

GEOLOGICAL EXPLORATION OF THE FORTIETH PARALLEL, FROM SIERRA NEVADA TO THE EASTERN SLOPE OF THE ROCKY MOUNTAINS.

U. S. GEOLOGICAL EXPLORATION OF THE 40TH PARALLEL,
New York, September 20, 1874.

GENERAL: I have the honor to present herewith a brief annual report of the operations of the geological exploration of the fortieth parallel, under my charge, from July, 1873, to the present time.

My corps of assistants has consisted of two geological assistants, one topographer, a clerk during one month, (July, 1873,) one messenger, and one microscopical assistant, the latter from April last to the present time.

FIELD-WORK.

The only field-operation undertaken during the year was a reconnoissance-journey, made by me in the autumn of 1873, and extending from September 2 to December 13. During that journey I visited and examined the White Mountain Range in California, with its important ancient rocks and mining districts. Also the mining regions of Pioche, Hamilton, Eureka, Austin, and Toyase, all in Nevada; the first locality for pure geological research, and all the Nevada localities, to study the dependence of mineral districts on local geology. The results of these examinations were admirably satisfactory, but cannot be intelligently treated within the necessarily narrow limits of a report like this. It may be, however, generally stated that the *Silurian*, and probably the *Archæan*, formations were recognized in California, and that the comparative study of the mining districts has developed a most interesting classification, dependent upon wide geological causes.

TOPOGRAPHY.

During the year, all the series of topographical maps (proper) have been completed on a scale of 4 inches to the mile. The last plats were reduced to the common scale, and the hill-draughting completed. This series consists of ten sheets, each 20½ inches by 26¾ inches, neat-line measurement, representing a continuous belt of country from the one hundred and fourth meridian to the one hundred and twentieth.

Along the fortieth, forty-first, and forty-second parallels of latitude, the hill-work, instead of hachures, is represented by brush-shading with an oblique light, and is intended to have this effect reproduced in lithographic crayon-ink, that being the only means within the limits of our funds. One of these ten sheets has been in the hands of Mr. Julius Bien for eight months and is now being proved.

I have delayed this report until now, hoping for weeks to be able to accompany it by a specimen proof-sheet, but I shall be unable to forward it for ten days yet. I can only say that, judging from the stone and preliminary proofs, a very creditable result may be expected.

The ten companion sheets of grade-curve topography, designed to be the basis for geological maps, are also engraved, and are now receiving their lettering and altitudes, and are undergoing correction for engraver's errors in grade-curve work. They are on the same scale as the topographical maps. Upon these we are coloring the geological formations, and upon them finally will be printed the geological charts.

The original plats of field-work, on a scale of two miles to the inch, have all been put in order to go on record at the Engineer Department. Such as in the first instance were not on good permanent paper are now transferred to new sheets, and the whole series, although ready to be transmitted to headquarters, are retained here at present for reference. Should the specimen-sheet of topography prove satisfactory, it is expected that four engravers will be at once put on the remaining nine sheets, and that all may be completed in ten months.

GEOLOGY.

The preparatory work for the two geological volumes has gone on uninterruptedly during the year, consisting of chemical analysis, microscopic study of the sedimentary rocks, (paleontology preparation of rock-slides for examination under transmitted light,) and preparation of illustrations.

CHEMISTRY.

There are now completed studies of the chemistry of the thermal and saline waters of our Great Basin region; also of the numerous alkaline deposits of Nevada and Utah, (within our limits,) many of which are of commercial value.

Analyses have also been made of the tufaceous deposits of the lake terraces of Pyramid and Salt Lakes, illustrative of the condition of the lime-charged lakes, of which the present sheets of water are but shrunken relics. We are now engaged upon silicate analysis, designed to settle certain difficult points in the composition and classification of the crystalline rocks. These latter, necessarily the slowest of all our chemical work, are, however, progressing as rapidly as possible, and will be continued during the present year. When assembled the whole chemical work will be found to touch only such points as are quite necessary for the intelligent description of localities. The whole amount of analytical work might have been profitably devoted to single divisions of our study, and although it may seem large in the aggregate, chemical inquiry has only been directed to the few necessary problems.

MICROSCOPIC STUDY.

Twelve hundred illustrative slides (or thin sections) of typical species and varieties of rocks have been made within the year, and are now being actively studied. This branch of investigation is one of the newest additions to geological study, but has become essential wherever a considerable variety of crystalline rocks are to be classified. This is peculiarly the case in the treatment of a region so rich in varied volcanic products as ours. Although our studies have commenced but recently, important observations have already been made.

Together with the chemical results, this microscopical work is enabling us to identify the whole of our collection of rocks with the known petrographic types of Europe, a labor not hitherto attempted in this country on any considerable scale. In this I am now receiving the co-operation of Dr. Ferdinand Zirkel, professor of geology in the University of Leipzig, the most eminent authority in Europe. He is examining with us the crystalline rocks, and Dr. Wright is at work upon the microstructure of the sedimentary rocks.

As authorized we have imported a first-class binocular lithological microscope, with complete accompanying appliances for polarization and spectroscopic work. This instrument, selected with much care by Mr. S. F. Emmons, in England, proves admirably adapted to our needs.

PALEONTOLOGY.

The unhappy failure of Prof. B. F. Meek's health has caused me much delay and anxiety as to a completed paleontological report. The fossil material not already worked up by Meek was, in July last, given to Messrs. Hall and Whitfield, of Albany, who promise to bring their work to a close in October. As soon thereafter as their few illustrations are lithographed, the volume IV, already more than half in type can be rapidly brought out.

GEOLOGICAL ILLUSTRATIONS.

The preparation of geological maps and illustrations has been and is now pushed as rapidly as possible. They consist of the ten atlas geological maps of views of interesting geological objects and localities

now being put upon stone, besides relief and orographical diagrams and stratigraphical sections. The latter will progress *pari passu* with the text, and are now under way. A series of eleven colored plates are also in progress, illustrating important geological views in which color plays an important part. They are to be chromo-lithographed for volume I.

GENERAL.

It will require six or eight months more to complete the preparation of all the detailed work necessary for the final reports and their illustration. The entire past year has been devoted to this labor, and we are now able to look forward to a speedy completion of all the preliminary questions undertaken by us. With the chemistry, microscopy, paleontology, and illustrations all off our hands there will remain only to complete the text, the least laborious and time-consuming part of our long research. It is my hope and intention to have everything completed within a year from this time, and, if possible, printed.

Very respectfully, your obedient servant,

CLARENCE KING,
Geologist in Charge.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. Army.

APPENDIX FF.

ANNUAL REPORT OF LIEUTENANT GEORGE M. WHEELER, CORPS OF ENGINEERS, FOR THE FISCAL YEAR ENDING JUNE 30, 1874.

GEOGRAPHICAL EXPLORATIONS AND SURVEYS WEST OF THE ONE HUNDREDTH MERIDIAN, IN CALIFORNIA, NEVADA, UTAH, ARIZONA, COLORADO, NEW MEXICO, WYOMING, AND MONTANA.

Season's operations.

UNITED STATES ENGINEER OFFICE,
GEOGRAPHICAL EXPLORATIONS AND SURVEYS
WEST OF THE ONE HUNDREDTH MERIDIAN,
Washington, D. C., June 30, 1874.

GENERAL: I have the honor to submit the following annual report upon geographical explorations and surveys west of the one hundredth meridian, in California, Nevada, Utah, Arizona, Colorado, New Mexico, Wyoming, and Montana for the fiscal year ending June 30, 1874.

Toward the close of the last fiscal year, the expedition of 1873 had taken the field in three separate divisions from Salt Lake City, Utah, Denver, Col., and Santa Fé, N. Mex.

The Salt Lake division, under Lieut. R. L. Hoxie, Corps of Engineers, crossed the Colorado River near the mouth of Paria Creek, emerging upon the mesa to the southward, in the vicinity of El Vado de los Padres; from thence making its way to the southward, joined the southern or main division, operating in the territory in New Mexico and Arizona but little known, lying between the thirty-fifth and the thirty-second parallel after it had completed the duties assigned to it in atlas rectangles 50 and 59.

Each division was accompanied by a small escort. These escorts were (with the exception of one corporal and six men, with Lieutenant Hoxie, detailed from the military department of the Platte, General E. O. C. Ord commanding) drawn from the military department of the Missouri, General John Pope commanding, the larger portion of the latter having been detailed from the military district of New Mexico, Col. J. Irwin Gregg commanding. These escorts were distributed among the several working field-parties, and were in numbers sufficient only for the protection of the lives of the members of the expedition and for guarding the public property. The necessary number of guides, packers, herders, laborers, &c., accompanied the expedition.

The Denver division, or Colorado party, under Lieut. W. L. Marshall, Corps of Engineers, was occupied for the entire season in Colorado, and completed most successfully the duties assigned to it in that field.

Executive reports submitted by Lieutenants Hoxie and Marshall are herewith.

Report of Lieut. R. L. Hoxie, Corps of Engineers.

UNITED STATES ENGINEER OFFICE,
GEOGRAPHICAL EXPLORATIONS AND SURVEYS
WEST OF ONE HUNDREDTH MERIDIAN,
Washington, D. C., January 1, 1874.

SIR: I have the honor to submit the following executive report of operations under my charge during the field season of 1873:

The party to which I was assigned as executive officer in charge was organized at Salt Lake City, Utah, and consisted of Gilbert Thompson, topographer; Edwin E. Howell, geologist; William Somers, meteorologist; Alexander Brown, odometer recorder; one cook, one cargadore, and four packers, with an escort of one sergeant and five privates from the military Post of Beaver, Utah.

The party left Salt Lake City on May 30th, and operated, until September 7th, east of the Wahsatch Mountains, in Castle Valley, working its way southward to the Colorado River, over the western part of Castle Valley, the portion of country required to complete atlas sheets Nos. 50, 59, and 67, at that time preparing for publication.

On the 7th of September we crossed the Colorado River and proceeded by way of Oraybe and the Moquis Pueblos to Fort Wingate, N. Mex., whence, after refitting, we proceeded southward, co-operating with the other parties in New Mexico and Arizona Territories, and, returning at the close of the season, disbanded at Fort Wingate on the 25th of November.

During the three months' operations in Utah about fifteen hundred topographical and triangulation stations were occupied, and one thousand and twenty-five miles of meander lines measured, besides which numerous detours were made for the ascent of prominent points as triangulation stations. The latitude and departure of camp was computed each night, the meander lines of the day plotted, and the principal topographical features drawn upon the field-map. Sextant observations for latitude upon north and south stars, and observations on Polaris for magnetic declination, were taken at each camp. The meridian of Provo was connected with that of the observatory at Salt Lake City, time-signals having been sent over the wires of the Deseret Company, freely tendered to the expedition by the courteous action of D. Milton Musser, superintendent.

The cistern and aneroid barometers, with the psychrometer, were read at regular intervals in camp and at all points that would serve to indicate the relief of the country.

About six thousand square miles of a very difficult mountain and cañon country was mapped here.

The accuracy of the work depends upon the triangulation and the latitude-checks. The former was entirely upon natural objects, the peaks of the Wahsatch range, the Henry Mountains, Navajo, and prominent mesas, and made with the gradienta by Mr. Thompson, who has shown more than ordinary skill and energy in performing rapid and accurate work. We derived much assistance from Mr. Howell, whose investigations in geology were necessarily carried on in intimate connection with the topography.

The sextant observations were made entirely by myself, and the average probable error of the results is about ten seconds of arc.

More time was taken in this part of our field of operations than allowed by your instructions, but this was necessitated by the obstacles encountered. In the month of June we found the high passes of the Wahsatch Range blockaded with snow and mud, and the streams on the eastern slope were swift, cold, and deep, causing serious detentions.

Later in the season we had worked our way southward into the cañon country, in which progress was necessarily slow, and a scarcity of grass and water added to the difficulty of traversing the country. At this time two of my packers deserted with thirty-two mules, and caused a further delay of about twenty days. The time was usefully employed, however. The full working force kept the field as usual, and although I had not intended to give the time here, the work done in consequence could not well have been dispensed with. The recovery of the mules, with the men who ran them off, cost me a chase of four hundred miles, the return being accomplished in two hundred more, over the wildest part of a difficult country.

We encountered considerable hardship during this part of our season's work, being frequently without good water, and sometimes without any. At one time we subsisted for seven days upon hard corn, brought along for the mules, and taken from them when they could ill spare it.

It was not possible to sacrifice close work to the pressure of time, as the devious track which covered so much ground was forced upon us by the difficult nature of the country.

A portion of the results of this part of the season's work are already published in Atlas sheets Nos. 50 and 59, and Mr. Howell will report upon the geology and mineralogy of the country so far as observed by him.

From the crossing of the Colorado to Fort Wingate, the most direct route was taken and no attempt was made to map the country through which we passed. The trail was carefully meandered, however, the topography adjacent sketched in, and frequent bearings taken as checks upon prominent points, with the usual latitude-checks for the camps and the observations with cistern barometer, aneroid, and psychrometer. The primiary object here was celerity of motion, the survey recommencing at Fort Wingate. The length of measured meander line was about two hundred miles.

Soon after leaving Fort Wingate Mr. Thompson was detached by your order, with a small party, to carry a system of triangles over the ground covered by my own and the other parties then operating together in New Mexico. This work was successfully accomplished. Base lines

were measured at Fort Tulerosa and Fort Bayard, and others located to be measured next season.

The work of my own party in this section of the country was conducted in the same manner as in Castle Valley during the earlier part of the season; but, having much more favorable conditions, better results were obtained.

About five thousand square miles were covered along the Atlantic and Pacific divide, in the section of country embraced in Atlas sheets Nos. 76, 83, 77, and 84.

This has been mapped and is ready to be transferred to the Atlas sheets.

Detailed reports of the geology and mineralogy of the region traversed will be submitted by Mr. Howell and Dr. Oscar Loew.

Very respectfully, your obedient servant,

R. L. HOXIE,
Lieut. of Engineers, U. S. A.

Lieut. GEO. M. WHEELER,
Corps of Engineers, U. S. A.

Report of Lieut. W. L. Marshall, Corps of Engineers.

UNITED STATES ENGINEER OFFICE,
GEOGRAPHICAL EXPLORATIONS AND SURVEYS
WEST OF THE ONE HUNDREDTH MERIDIAN,
Washington, D. C., June 30, 1874.

SIR: I have the honor to submit the following executive report of the operations of the Colorado party of the expedition for explorations and surveys west of the one hundredth meridian, during the field season of 1873.

In accordance with the annual project, approved by the Secretary of War and Chief of Engineers, and pursuant to instructions from you, I organized the party at Denver, Colo., about June 1, 1873. Its *personnel* was as follows: First Lieut. W. L. Marshall, United States Engineers, executive officer and astronomer; Dr. J. T. Rothrock, acting assistant surgeon, United States Army, surgeon and naturalist; Prof. J. J. Stevenson, geologist; J. J. Young, topographer; Edgar Schroeder, assistant topographer; Prof. John Wolf, collector in botany; Bernard Gilpin, meteorologist, and a small escort of enlisted men from the Fifth Infantry. Including packers and employés the party numbered forty-two men. Later in the season we were joined by Mr. Louis Nell, chief of triangulation. Pending the organization of the main party, on the 8th day of June a small topographical party was sent out to define the bases of the mountains, or "hogsbacks," from the mouth of the Platte Cañon to Golden City, with orders to join the main party at Georgetown, Colo., on the 16th.

On the 17th of June, having received at Georgetown the necessary supplies, I sent the main party, under Dr. Rothrock, to encamp near Fair Play, in South Park, to allow the collectors in natural history an opportunity to make full collections in the several branches in that vicinity, and to establish a meteorological station at the permanent camp. My small party retraced their course to Idaho Springs, visited the mines at Central City and Black Hawk; thence, by way of Chicago Lake and Mount Evans, to Georgetown, making the necessary topographical stations. On June 22 the Atlantic and Pacific divide was crossed

at the Argentine Pass, and from this date to July 4 the party worked about the heads of the Blue and Platte Rivers, in the cross range between Middle and South Parks, and in the Blue River range, making the ascent of Lincoln Peak and such other stations as were necessary to give a knowledge of the topography of this region.

Leaving the collecting party at Fair Play with orders to move camp to Twin Lakes, on the west side of the Upper Arkansas River, by August 1, the field party proceeded to survey the mountain-ridges bounding South Park, examined the country about the heads of the North Fork of the South Platte; the Kenosha range from Mount Evans to the Platte and Arkansas divide; this divide from the southeastern limit of South Park to the head of the South Fork of the South Platte River, meandering en route the principal roads and streams, and making the necessary stations upon mountain-peaks to check by triangulation the principal points of the survey. Wet Mountain Valley was visited, and the Arkansas River traced from near Cañon City to Granite C. H., at which place we arrived August 1, 1873.

During this interval, July 5 to August 1, Mr. Schroeder was employed with a small topographical party in collecting topographical data and in meandering roads and streams in South Park not traced upon the plats of the General Land-Office, and not visited by my own party.

From the non-arrival of supplies forwarded by the Quartermaster's Department from Cheyenne, a delay of several days was necessitated, which interval was spent in the immediate vicinity of Twin Lakes in collecting topographical details. A base was measured and an accurate trigonometric survey of the lakes made, and the topographical features relatively located from it. Two lines of soundings across either lake were made at the request of Prof. Stevenson.

On the 6th of August, having purchased the necessary supplies, the geologist and topographer were sent to visit the mines at Oro City, Colo., and McNutty gulches, and Homestrike Mountain, and to examine the country about Ten-Mile Creek, one of the tributaries of the Blue River; the western slope of the Blue River range; to meander Eagle River and its main branches, and to define the northern limit of the main or Saguache range west of the Arkansas River.

This party having accomplished its object, returned to the permanent camp at Twin Lakes on August 18. On the following day, still leaving the collecting party at Twin Lakes with facilities to extend the field of their investigation wheresoever they pleased, two topographical parties were dispatched—Mr. Schroeder, assistant topographer, to collect topographical data and meander the streams flowing into the Arkansas north of Lake Creek; to fix the water-shed and locate the heads of the middle branch of the Roaring Fork of the Grand River; while my own party crossed the divide at the head of Lake Creek, and from August 19th to September 3rd were engaged about the heads of the Gunnison River, and the southern tributaries of the Roaring Fork of the Grand River stations were made upon prominent peaks in the Elk Mountains, and also in the Saguache range at the heads of Chalk and Cottonwood Creeks, and the cañon of Taylor River traced to the junction of this stream with East River.

On the 3d of September the party was joined by Mr. Nell, chief of triangulation, from Fort Wingate, N. M.

On September 5th, he was sent with orders to make triangulation stations near the junction of the Eagle and Grand, at the northern extremity of the Saguache range, in the Blue River range, upon Gray's Peak and Mount Evans, connecting the former with the astronomical

point at Georgetown; thence to proceed by the shortest road to Pike's Peak, which point had been located from a base measured near the astronomical station at Colorado Springs by Dr Kampf, making secondary stations *en route;* thence *via* the southern rim of South Park and the Platte and Arkansas divide to South Arkansas Creek, and thence to Fort Garland, making the necessary stations to give a connected system of triangles from the northern to the southern limit of our survey, from which points those occupied by Messrs. Young and Schroeder could be fixed. These orders were carried out by Mr. Nell, except that he was prevented by snow from actually occupying one of the main stations near the head of the South Arkansas, suggested to him. This point, though quite accurately fixed in longitude and latitude, must be occupied the coming season.

From September 5 to October 10 two parties were continuously employed in completing the survey of the drainage-areas of the upper Arkansas, and that part of the area drained by the Gunnison River which lies east of the one hundred and seventh meridian. From the 10th of October to November 4 a line-survey was run up the valley of the Rio Grande River to the San Juan mining district, but snow, which fell to the depth of 13 inches on the 15th, 16th, and 17th of October, prevented any further work in this region at high altitudes and effectually prevented any main stations on mountain-peaks. The Las Animas River was headed, and a line run down this stream connecting with Mr. Nell's trail from Fort Wingate, thence *via* the Pagosa Hot Springs, Tierra Amarilla, and the head of the east branch of the Chama, and the San Antonio River to Fort Garland.

The streams tributary to the Rio Grande from the west and its main South Fork had meanwhile been meandered by a small party. The Sangre de Christo range south of Fort Garland as far as the New Mexican line was also surveyed by Mr. Young. The interval from November 4 to November 14 was employed by Mr. Nell in measuring a base near Fort Garland and expanding it to his triangulation-stations.

A small party under the direction of Dr. Rothrock was dispatched on November 9 to Denver *via* Wet Mountain Valley, the Hardscrable Mines at Rosita, the Coal Mines at Cañon City, Colorado Springs, and mouth of Platte Cañon, to define the limits of the foot-hills and meander certain roads and streams. This party arrived at Denver December 4th, 1873. The measurement of the base and the local triangulation about Fort Garland having been completed, the escort returned to its station and the supernumerary employés were discharged. My party left Fort Garland November 14, and proceeded, *via* the Aheyta Pass, to the east of the Sangre de Cristo range, headed the Cucharas, the Apishpa, the Purgatoire, and the North Fork of the Canadian River, made a triangulation-station upon the Greenhorn Mountain; then proceeded *via* Mace's Hole, Red Creek, Cañon City, Oil Creek, the Cañon of the South Platte, North Fork of the South Platte, and Turkey Creek, to Denver, making the necessary topographical stations *en route*, and, with the lines already run by Messrs. Nell and Young, completing the survey of the foot-hills. On the 10th day of December the parties were disbanded at Denver, Colorado.

METHODS OF SURVEY.

The two peaks, Gray's and Pike's, were located from the astronomical stations at Georgetown and Colorado Springs, C. T., and the computed length and azimuth of the line connecting them were used as a base for our triangulation.

During the season thirty-six peaks, over 13,000 feet in height, were occupied, and many others of less altitude, which were fixed by triangulation processes. At the main points, the angles, repeated, were read from an instrument made by Stackpole, 8″ circle, graduated to read by vernier to 10″ of arc. At other important points a gradienta was employed. In addition to the mountain-work, nearly five thousand miles of roads and streams were meandered; the angles being read from a Casella theodolite and the distances measured by an odometer, checked by angles to fixed points, and by sextant observations made by myself for latitude. The area covered is nearly twenty-one thousand square miles.

METEOROLOGY AND HYPSOMETRY.

At all camps cistern-barometer readings were taken tri-daily when the camps were for an entire day or more, and at 7 a. m. and 9 p. m. when *en route*.

The altitudes of mountain stations were determined by cistern-barometer observations, referred either to our main camps or to the astronomical hourly stations, and by vertical angles from barometric and trigonometric bases.

At topographical stations along roads and streams aneroid readings were taken. The profiles of nineteen passes, eleven over the Atlantic and Pacific divide, and eight over subordinate ranges, were taken, and the slopes of many beds of streams near their heads determined.

GEOLOGY.

Prof. J. J. Stevenson, of New York, accompanied the party as geologist, and his report, already submitted, attests the ability and zeal with which he worked in spite of the necessarily limited facilities that could be afforded.

NATURAL HISTORY.

Dr. J. T. Rothrock and assistant John Wolfe were offered every facility and aid in my power in making collections in natural history, and the results, especially in botany, have probably never been equaled by any exploring or surveying expedition to the West. Nearly 12,000 specimens of plants from over 1,100 different species, and large collections in other branches of natural history, were gathered by these gentlemen, and are now being worked up.

To these and the other gentlemen of the party, for their efficient aid and exertions during the field-season, I desire to return my thanks.

Respectfully submitted.

W. L. MARSHALL,
First Lieutenant of Engineers.

Lieut. GEO. M. WHEELER,
Corps of Engineers, in charge.

The division moving out from Santa Fé accomplished during the season, with the assistance of the Salt Lake division, the survey of 11,000 square miles in the Territory of New Mexico, and 17,500 in Arizona, in a region possessed of remarkably interesting topographical features. The total area surveyed during the entire season was, approximately, 72,500 square miles. The degree of accuracy of the survey was considerably in advance of that of former years. The connecting station for astronomical signals of the main parties was at the Mormon observatory, Salt Lake City, until late in September, when it was transferred

to the observatory constructed under the auspices of the survey, at Ogden, Utah. Several astronomical parties were remarkably fortunate in carrying out their observations at all points selected, which were twelve in number, making it notably an astronomical campaign of a single season, marked by the most successful results. The parties are again about to take the field to continue their labors in southern and southwestern Colorado, northern and northwestern New Mexico, and northwestern Arizona. The geographical area to be occupied is represented by Atlas rectangle No. 69, southwestern quarter of No. 61, western half of No. 70, and portions of No. 68. The equipments and preparations, notwithstanding the late date of commencing the latter, are better than ever before, and the addition of a few new members to the organization has established for each of the parties an efficient *personnel*.

The number of applications by young men, graduates of the several scientific schools of the country, besides gentlemen of professional note, has been much greater than heretofore, and it is believed will increase from year to year.

The following officers and civilian assistants have been connected with the survey during the season or portions thereof: First Lieut. R. L. Hoxie, Corps of Engineers, in charge of main field party No. 2, until the close of field operations; since that time in charge of the meteorological branch of office; Lieut. Wm. L. Marshall, Corps of Engineers, in charge of main field party No. 3, and of astronomical work in the office, and since March 24 in charge of topographical branch; Lieut. S. E. Tillman, Corps of Engineers, reported for duty upon the survey on the 29th of August, and from that date until the close of field operations was in charge of main party No. 1, and of topographical branch of the office until March 24, when he was relieved and ordered for duty upon the observations for the transit of Venus; Lieut. Philip M. Price, Corps of Engineers, reported for duty on the 27th of June, 1874. Second Lieut. A. H. Russell, Third United States Cavalry, was connected with the work during the year until February 4, 1874, as acting assistant quartermaster, assistant commissary subsistence, and ordnance officer to the expedition. In addition to these duties he was in charge of a portion of main field party No. 1, during field operations, and afterward employed in the settlement of his accounts and reduction of his topographical work, until relieved. Lieut. H. R. Brinkerhoff, 15th United States Infantry, was detailed as escort officer to the expedition, in which capacity he served until July 5, 1873, when he was relieved by Second Lieut. L. H. Walker, Fifteenth United States Infantry, who in addition had charge of a small party in its operations from Fort Wingate to Fort Tulerosa, New Mexico, until close of field operations.

Acting Assistant Surgeon J. T. Rothrock, United States Army, was on duty with the survey during the entire season; Acting Assistant Surgeon H. C. Yarrow, United States Army, from January 31, 1874, and on the 3d of February was assigned to the charge of the natural-history branch of the survey, in addition to his other duties. Acting Assistant Surgeon C. G. Newberry, United States Army, reported for duty on the 7th of May, 1873, in compliance with instructions of the Surgeon General United States Army, and continued with the work until January 31, 1874, when he was relieved and his contract annulled.

Hospital Steward Theodore V. Brown has been on duty with the survey during the entire year until May 1st, when he was granted furlough for three months, with permission to go beyond the sea.

In the astronomical branch of the survey Civilian Assistants Dr. F. Kampf, William W. Marryatt, J. H. Clark, Professor S. H. Safford, and

Professor H. B. Herr have been engaged—Dr. Kampf during the entire year; Mr. Marryatt from July 1, 1873, to October 8, 1873, when his death occurred, at Bozeman, Montana; Mr. Clark from July 1 to April 1, 1874; Professor Safford for seven months; Professor Herr until August 25, 1873.

Assistants Louis Nell, Gilbert Thompson, J. J. Young, E. J. Sommer, Max E. Schmidt, R. J. Ainsworth, and, at times, Francis Klett and Edgar Schroeder have, under direction of the officers in charge, conducted field topographical work, and during the winter have been engaged in the reduction of their notes and plottings.

Assistant F. M. Lee has been employed during the entire year in the reduction of barometrical observations taken by the several parties.

In the reduction and presentation of topography Messrs. Weyss and Herman have been engaged during the whole year, and Messrs. Lang, Philp, and Aquirre a portion thereof.

In the natural history branch Assistants H. W. Henshaw, George M. Keasby, and John Wolf were employed in making collections in the field, and Mr. Henshaw, during the winter, classified and arranged specimens collected.

Mr. T. H. O'Sullivan, photographer, secured forty-two landscape views and one hundred and four stereoscopic views, a portion of which will be published.

Mr. A. H. Wyant, artist, traveled with the photographic party, and made studies of some scenes in the Cañon de Chelle, one of which he proposes to put on canvas when his health will permit.

Assistants G. K. Gilbert, Prof. John J. Stevenson, E. E. Howell, and Oscar Loew were employed during the year in geological researches in the field, and compilation of results during the winter. Dr. Loew has made many interesting analyses regarding minerals, soils, &c. In the general duties pertaining to the work, both in the field and the office, I have been ably and faithfully assisted by Assistants W. D. Wheeler and J. B. Minick. I have again the agreeable duty of reporting the courtesies extended to the survey by the officers of the Western Union Telegraph Company, and the use of wires of that company over lines extending from Salt Lake City westward to Virginia City, Nev., eastward to Cheyenne, and thence southward to Santa Fé; and northward from Ogden, Utah, to Helena, Mont. Mr. Hibbard, the superintendent at Salt Lake City, made, with commendable zeal, all the arrangements necessary to carry out this extended programme, in which he was seconded by Mr. Woodward, manager at Denver, Colo.; as likewise the operators at Cheyenne, and at all the points from whence signals were sent and received.

The Atlantic and Pacific Telegraph Company extended also the free use of their lines. Messages for longitudinal difference were also sent over the lines of the Deseret Telegraph Company from Richfield, Utah, by Lieutenant Hoxie. Mr. Thomas Largey afforded the use of his lines from Helena to Bozeman, Mont., at reduced rates. We were thereby enabled to fix the geographical position of this important point agreeably to the wishes of Bvt. Maj. Gen. E. O. C. Ord, commanding the Department of the Platte, it being one of the extremities of the routes surveyed by Capt. William A. Jones, Corps of Engineers, from the Union Pacific Railroad to the head-waters of the Yellowstone, and beyond. Longitude connection was made between the observatory at Ogden, Utah, and that of the United States lake survey at Detroit, Mich.; Maj. C. B. Comstock, Corps of Engineers, detailing at the Detroit end of the line Assistant O. B. Wheeler for that purpose.

The officers of the United States Naval Observatory have, as heretofore, extended kind assistance to the survey.

The only casualty to be noted during the year has been the death, from fever, of Astronomical Assistant Wm. W. Maryatt, while engaged in carrying on his observations at Bozeman, Mont. This was one of the last stations to have been occupied by him during the season. He had gone forward, after having been very successful at the other stations, and was stricken down soon after reaching Bozeman, and, after a short and severe illness, died at that point. The survey lost a most valuable assistant, and the profession of astronomy an accurate, faithful, and zealous worker.

ASTRONOMICAL BRANCH.

The classes of astronomical work conducted by the survey have been of two distinct grades:

1st. Those at the main or primary station, where, by the most refined methods and use of the best class of instruments, the astronomical co-ordinates are determined with the utmost accuracy, and the meridian line of the point carefully established.

2d. At positions in the field, where, in order to carry out the scheme of survey, sextant latitude checks are required, and at other points where, the telegraph being accessible, the meridian is determined by comparing local times, the watch-errors having been obtained by sextant observations. The latter class of stations are more or less numerous, in accordance with the character of the area surveyed, and of the points within the same whose position can only well be determined by this means.

The others are at specifically-selected points near the fields of survey, and from which, measured and developed, bases controlling the triangulation can easily be laid out.

The main or primary points occupied during the season of 1873 were:

1. Georgetown, Colo.
2. Hughes, Colo.
3. Colorado Springs, Colo.
4. Labran, near Cañon City, Colo.
5. Trinidad, Colo.
6. Ogden, Utah.
7. Green River, Wyo
8. Winnemucca, Nev.
9. Virginia City, Nev.
10. Bozeman, Mont.
11. Santa Fé, N. Mex.
12. Fort Union, N. Mex.

OBSERVATORY AT OGDEN.

A substantial observatory, of three rooms, with brick superstructure and stone foundations, has been built at this point. The walls are completed, but the dome and the middle observing-room are yet unfinished.

The co-ordinates of this position, as referred to the meridian established by the United States Coast Survey at Salt Lake City, and that of the United States Lake Survey at Detroit, Mich., have been determined. In the season of 1874 it is intended to exchange signals with the United States Naval Observatory at Washington, and resulting therefrom another check will be introduced. The several results will be discussed in the astronomical volume. The meridian of Ogden will then be assumed

as the standard of reference for the future astronomical positions determined by the survey.

There are submitted results from the reports upon the determinations of the astronomical co-ordinates of the following main or primary stations: 1. Carlin, Nev.; 2. Battle Mountain, Nev.; 3. Austin, Nev.; 4. Saint George, Utah; 5. Fort Whipple, Ariz.; 6. Fort Fred Steele, Wyo.; 7. Laramie, Wyo.; deduced from observations made during the years 1871 and 1872.

CARLIN, NEVADA.

Geographical position—longitude, 116° 7′ 20.6″, latitude, 40° 42′ 26.67″

The astronomical station is situated west-northwest from Carlin, Nev., 344 feet from the track of the Central Pacific Railroad, and 1,406 feet from the Humboldt River, which is due south, and 550 feet from the railroad-bridge over a small creek entering the Humboldt from the south. The town has nearly 2,000 inhabitants, and is mainly located from east to west along the railroad-track.

Physical geography details.—The ground around the station is level to the east and west; at a distance of 2,000 feet south and north a gentle rise commences. At a distance of two or three miles some slight hills, not more than 500 to 800 feet above the station, are visible. The elevation of the monument above the level of the sea is determined approximately to be 5,000 feet.

Meteorological conditions.—No meteorological observations of a general or special kind were made during the time of observations. As far as can be seen from the diary of the observer, there was a great diurnal change of temperature, by which the rate of the chronometer was much affected.

Description of observatory.—The observations were taken in a common wall-tent, 10 by 10 feet, with an opening for the meridian line. The telegraphic instruments were placed in the northeast corner. The wires of the Western Union Telegraph Company were used for exchange of signals. The observer had no assistance but, Carlin being the starting-point for all parties, Mr. Francis Klett acted as recorder during the time he was present.

Description of instruments.—The astronomical instrument was a combined transit, made by Würdemann, numbered 16. It was of 26 inches focal length and 1½ inches aperture, and mounted on four pieces of red-wood scantling 4 by 4 inches, which were planted in the ground about 4 feet, and fastened together above by board cross-pieces. For telegraphing, a switch-board was used, a description of which will be found in the report on Colorado Springs, Col. The observations were taken by eye and ear, using the sideral chronometer Negus 1314; for the exchange of signals, mean solar chronometer Hutton No. 288 was always used.

Points with which connections were made were with the United States Lake-Survey Observatory at Detroit, Mich., and the United States Naval Observatory at Washington, D. C.—Detroit receiving the signals sent from Carlin and Washington. Signals were sent on May 19, 23, and 24, 1871. Carlin was occupied by E. P. Austin; the observations at Detroit were conducted by Mr. O. B. Wheeler, assistant, United States Lake-Survey; at Washington, by Prof. John R. Eastman, United States Naval Observatory. The computations relating to Carlin and also the arrangement of the report were made by Dr. F. Kampf.

Instrumental values, &c.—The value of one division of the striding-level was 1.14″; the value of one division of the zenith-level was 2.70″; of one revolution of the micrometer screw, 80.86″. The wires of the

Western Union Telegraph Company were brought into the tent by a loop. By means of automatic repeaters the signals were sent to the connected stations—the repeaters being placed at Corinne, Cheyenne, Omaha, Chicago, Pittsburgh, and Philadelphia.

In relation to the personal equation, I have to state that, as far as it is known in this office, this value for the relative error of the observers has not been determined. Mr. Austin was in Washington in the spring of 1873 for this purpose, but no satisfactory results were obtained. The resulting longitude is therefore affected by this relative error.

OBSERVATIONS TO DETERMINE THE CLOCK-CORRECTION AT THE UNITED STATES NAVAL OBSERVATORY.

The instrument used in these observations is that known as the "meridian transit," which has been employed at the Observatory for many years, and is now situated in the east wing of the building. The description of this instrument may be found in the "Washington Astronomical and Meteorological Observations" for 1862.

The transit was employed in 1871, under the direction of Prof. M. Yarnall, United States Navy, in observing stars for the "General Catalogue;" and, as the observations for time used in the longitude work were made after the regular work with the instrument was finished for the night, the same observations for collimation were employed in reducing the time-stars as were used in the reduction of the regular work.

The system of transit-threads in this instrument is composed of five groups or sets. When the clamp end of the axis is east, the set which is first reached by a star in its transit at the upper culmination is known as set A, and the others as sets B, C, D, and E.

During the early part of 1871 the equatorial interval between each thread in the five sets and the mean of B, C, and D was found to be as follows:

Thread.	Interval.	Thread.	Interval.	Thread.	Interval.	Thread.	Interval.	Thread.	Interval.
	s.		*s.*		*s.*		*s.*		*s.*
A_1	37.897	.....	.....	C_1	3.183	D_1	15.146	E_1	30.003
A_2	35.972	.....	.....	C_2	1.654	D_2	17.589	E_2	32.647
A_3	34.308	B_1	19.216	C_3	0.014	D_3	19.110	E_3	34.153
A_4	32.745	B_2	17.563	C_4	1.639	.....	.....	E_4	35.820
A_5	30.205	B_3	15.069	C_5	3.221	.....	.....	E_5	37.693

The reduction for C^3 is $+ 0^s.014$ when the clamp end of the axis is east. The clock used is that known as the "mural clock," and is mounted against a stone pier in the transit-room. It is connected with the chronograph in the usual way, and closes the circuit at each second, except at the sixtieth second of each minute, when a small ivory lever on the axis of the escapement-wheel raises a very delicate spring, which forms a portion of the circuit, and prevents the closing of the circuit at that instant.

The observations of all except circumpolar stars were recorded in the usual manner by the chronograph, which is described in the annual volume for 1862.

In the reductions, whenever a broken set of observations occurred, each thread was reduced separately.

Instrumental corrections.—The corrections to the observed transit of a star were derived from the observed and computed errors c', n', and m'.

The error of collimation is represented by c'; the equatorial value of

the distance between the line of collimation and the true meridian at the pole, by n'; and the distance between the line of collimation and the true meridian at the equator, by m'.

The quantities represented by n' and m' are used instead of errors of azimuth and level.

By means of a collimating eye-piece, the error of collimation and level was determined by reversing the instrument over a basin of mercury, and measuring with the right-ascension micrometer the distance between the central thread (c_3) and its image reflected from the mercury.

Denoting by—

c, n, and m the corrections obtained from the observed and computed errors c', n', and m';

2Δ, the distance of the central thread *west* of its image when the clamp-end of the axis is east;

$2\Delta'$, the distance of the central thread west of its image when the clamp end of the axis is *west*;

p, the correction for the excess of the radius of the clamp-pivot=0^s.008;

r, the equatorial distance of the middle thread from the mean of sets B, C, and D=0^s.014;

a, the correction for diurnal aberration=0^s.016;

b, the level-correction;

α, the adopted place of the star;

α', the observed place of the star;

δ, the declination of the star;

φ, the latitude of the observing-station;

C′, the approximate clock-correction; and

C, the clock-correction derived from the observation of each star—

and we have the following formulas, which have been employed in reducing the observations for time:

n was determined from the observations of circumpolar stars.

The quantities Δ and Δ' are given in revolutions of the micrometer-head, each revolution =1^s.5865.

$$c=\tfrac{1}{2}(\Delta-\Delta')-p-r-a \text{ for clamp east.}$$

$$c=-\tfrac{1}{2}(\Delta-\Delta')+p+r-a \text{ for clamp west.}$$

$$b=-\tfrac{1}{2}(\Delta+\Delta')-p \text{ for clamp east.}$$

$$b=-\tfrac{1}{2}(\Delta+\Delta')+p \text{ for clamp west.}$$

$$n=\frac{\alpha-(\alpha'+\mathrm{C}'+c\sec\delta)}{\sec\delta}$$

$$m=-n\tan\varphi+b\sec\varphi$$

$$\mathrm{C}=\alpha-(\alpha'+m+n\tan\delta+c\sec\delta)$$

In the column "Adopted right ascension" in the following table, the places of the clock-stars are those used at the observatory in 1871, some of the Nautical-Almanac places being slightly changed.

Observed clock-corrections, United States Naval Observatory.

Date.	Number.	Object.	Seconds of transit over wires. I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	Mean.	Instrumental corrections.	Observed place.	Adopted right ascension.	Clock-correction.
1871.			*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*m.* *s.*		*s.*	*h.* *m.* *s.*	*s.*
May 19	1	ε Bootis	1.5	3.3	6.1	19.6	21.4	23.2	25.0	26.8	40.4	43.1	44.8	39 23.20	+ 0.08	23.28	14 39 22.64	−0.64
	2	β Bootis	.....	.....	.....	3.3	5.3	7.4	9.5	11.6	.....	.....	.....	57 7.42	+ 0.15	7.57	14 57 6.94	−0.63
	3	β Libræ	46.6	48.2	50.8	3.1	4.6	6.2	7.8	9.6	21.6	24.0	25.5	10 6.17	− 0.07	6.10	15 10 5.42	−0.68
	4	μ^1 Bootis	15.0	17.0	19.9	35.4	37.2	39.1	41.3	43.2	58.4	1.6	3.6	19 39.25	+ 0.13	39.38	15 19 38.76	−0.62
	5	α Coronæ Borealis	.....	.....	.....	32.8	35.5	37.0	49.5	52.4	54.0	56.0	58.1	29 15.70	+ 0.06	15.76	15 29 15.11	−0.65
	6	α Serpentis	37.7	39.3	41.8	53.8	55.3	56.9	58.6	0.2	12.2	14.6	16.2	37 56.96	− 0.02	56.94	15 37 56.29	−0.65
	7	ε Serpentis	.....	.....	.....	21.9	23.5	25.2	26.9	28.5	.....	.....	.....	44 25.20	− 0.03	25.17	15 44 24.60	−0.57
	8	δ Aquilæ	42.4	43.8	46.2	58.5	59.9	1.5	3.0	4.4	16.6	18.8	20.5	19 1.42	− 0.03	1.39	19 19 0.57	−0.82
	9	κ Aquilæ	39.3	40.9	43.8	55.4	57.2	58.8	0.5	2.2	13.9	16.5	18.2	20 58.79	− 0.06	58.73	19 29 57.93	−0.80
	10	γ Aquilæ	49.6	51.5	53.8	6.0	7.5	9.1	11.1	12.8	24.6	27.3	28.5	40 9.25	− 0.01	9.24	19 40 8.46	−0.78
	11	α Aquilæ	11.6	13.1	15.9	27.7	29.3	30.9	32.5	34.1	46.4	48.9	50.5	44 30.99	− 0.01	30.98	19 44 30.19	−0.79
	12	β Aquilæ	41.0	42.6	45.0	57.0	58.5	0.1	1.8	3.2	15.4	17.8	19.4	49 0.16	− 0.02	0.14	19 48 59.39	−0.75
	13	λ Ursæ Minoris	.....	.....	.....	54.5	17.0	40.0	7.0	31.0	.....	.....	.....	53 42.16	+14.87	57.03	19 53 56.20	.....
May 23	14	η Herculis	.....	.....	.....	.....	.....	.....	6.3	9.7	11.9	14.0	16.5	38 27.51	− 0.13	27.38	16 38 30.23	+2.85
	15	κ Ophiuchi	13.2	14.6	17.6	29.5	31.1	32.6	34.2	35.8	48.0	50.4	52.1	51 32.59	− 0.16	32.43	16 51 35.20	+2.77
	16	d Herculis	.....	28.3	31.3	45.6	47.6	49.5	51.5	53.4	7.8	10.8	.....	56 49.55	− 0.13	49.42	16 56 52.28	+2.86
	17	α^1 Herculis	25.1	26.5	.....	41.3	43.0	44.8	46.5	48.0	0.3	2.8	.....	8 44.74	− 0.15	44.59	17 8 47.40	+2.81
	18	δ Ursæ Minoris	51.0	16.5	58.0	20.5	45.0	14.0	44.0	6.5	29.5	11.0	40.0	14 14.18	− 0.77	13.41	18 14 16.13	.....
	19	δ Aquilæ	.....	.....	.....	13.2	15.7	17.3	28.5	31.0	32.5	.....	36.1	18 58.17	− 0.16	58.01	19 19 0.68	+2.67
	20	γ Aquilæ	46.6	48.1	50.5	2.7	4.5	6.1	7.7	9.2	21.5	23.8	25.6	40 6.03	− 0.15	5.88	19 40 8.57	+2.69
	21	α Aquilæ	8.4	9.8	12.2	24.5	26.1	27.7	29.4	31.0	43.0	45.7	47.1	44 27.72	− 0.16	27.56	19 44 30.30	+2.74
	22	β Aquilæ	37.8	39.3	41.7	53.9	55.4	57.0	58.6	0.2	12.2	14.6	16.3	48 57.00	− 0.16	56.84	19 48 59.50	+2.66
	23	τ Aquilæ	29.3	30.8	33.2	45.4	46.9	48.5	50.1	51.7	3.6	.....	7.8	57 48.51	− 0.16	48.35	19 57 51.13	+2.78
May 24	24	α Serpentis	35.1	36.4	39.0	51.1	52.5	54.1	55.8	57.2	9.5	12.1	13.9	37 54.25	− 0.11	54.14	15 37 56.33	+2.19
	25	ε Serpentis	3.4	4.9	7.4	19.5	21.0	22.7	24.2	25.7	37.8	40.3	42.1	44 22.64	− 0.11	22.53	15 44 24.66	+2.13
	26	ε Coronæ Borealis	52.9	54.6	57.2	10.9	12.5	14.4	16.2	18.1	31.5	34.3	36.2	52 14.44	− 0.09	14.35	15 52 16.43	+2.08
	27	δ Ophiuchi	15.5	17.1	19.7	31.5	33.1	34.7	36.2	37.8	49.8	52.2	54.0	7 34.69	− 0.13	34.56	16 7 36.67	+2.11
	28	δ Ursæ Minoris	.....	.....	.....	21.0	48.5	14.5	40.0	9.0	.....	.....	.....	14 14.66	− 0.51	14.15	18 14 16.26	.....
	29	α Lyræ	9.3	11.1	14.2	29.6	31.5	33.6	35.8	37.7	53.1	56.1	58.3	32 33.66	− 0.08	33.58	18 32 35.79	+2.21
	30	β Lyræ	55.4	57.3	0.3	14.5	16.3	18.4	20.3	22.3	36.4	39.4	41.5	45 16.37	− 0.09	18.28	18 45 20.43	+2.15
June 16	31	α^1 Herculis	29.7	31.4	34.1	46.3	47.9	49.7	51.4	52.9	5.3	7.8	9.6	8 49.64	− 0.22	49.86	17 8 47.65	+2.21
	32	α Ophiuchi	40.6	42.7	45.2	57.3	58.9	0.5	2.3	4.0	16.0	18.6	20.2	29 0.57	− 0.21	0.78	17 28 58.52	−2.26
	33	μ Herculis	.....	.....	.....	25.0	26.5	28.2	30.1	32.0	45.5	48.2	50.0	41 28.35	− 0.30	28.65	17 41 26.42	−2.23
	34	δ Ursæ Minoris	.....	.....	.....	21.5	48.0	15.0	41.5	9.0	.....	.....	.....	14 15.00	− 4.92	19.92	18 14 17.67	.....
	35	1 Aquilæ	.....	.....	.....	11.8	13.3	15.1	16.7	18.4	30.2	32.9	34.3	28 15.04	− 0.12	15.16	18 28 12.95	−2.21
	36	α Lyræ	13.5	15.5	18.9	34.2	36.1	38.0	40.1	42.1	57.3	0.7	2.7	32 38.10	− 0.36	38.46	18 32 36.20	−2.26
	37	β Lyræ	59.7	2.0	4.9	19.1	20.9	22.9	24.9	26.6	41.0	43.9	45.6	45 22.86	− 0.33	23.19	18 45 20.87	−2.32
	38	ζ Cygni	7.9	9.8	12.7	26.6	28.2	30.1	32.2	33.8	47.5	50.2	52.0	7 30.09	− 0.31	30.40	21 7 28.08	−2.32
	39	1 Pegasi	50.0	51.8	54.4	7.1	8.7	10.5	12.2	14.0	26.6	29.2	31.1	16 10.51	− 0.24	10.75	21 16 8.45	−2.30

Observed clock-corrections, United States Naval Observatory—Continued.

Date.	Number.	Object.	Seconds of transit over wires.										Mean.		Instrumental corrections.	Observed place.	Adopted right ascension.			Clock-corrections.
			I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.								
1871.			*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*m.*	*s.*	*s.*	*s.*	*h.*	*m.*	*s.*	*s.*
June 16	40	β Aquarii	29.9	31.5	34.0	46.0	47.6	49.2	50.9	52.5	4.5	7.1	8.5	24	49.25	− 0.13	49.38	21	24	47.15	−2.23
	41	ξ Aquarii	36.9	38.5	40.9	53.3	54.7	56.2	57.8	59.5	.....	.....	.....	30	56.27	− 0.12	56.39	21	30	54.09	−2.30
	42	ϵ Pegasi	34.8	36.5	38.9	51.0	52.6	54.2	55.8	57.4	9.5	11.8	13.5	37	54.17	− 0.20	54.37	21	37	52.09	−2.28

Nos. 2, 7, 13, and 28, set C.
14, set E.
16, B_1 and D_3 rejected.
17, B_3 and D_2 rejected.
19, sets D and E; E_4 rejected.
23, D_2 rejected.
33, sets C and D.
34, set C; cloudy.
35, sets C and D.
41, sets B. and C.

COLLIMATION.

May 19. 9. Image east 0r.16; clamp east.
Image west 0r.19; clamp west.
May 23. 9. Image west 0r.17; clamp west.
May 24. 9. Image west 0r.19; clamp west.
Image east 0r.10; clamp east.
June 16. 9. Image west 0r.20; clamp east.
Image west 0r.42; clamp west.
On the 23d and 24th the stars were very unsteady.

While observing on May 19 and June 16, the clamp was east, and west on the 23d and 24th of May.

The values of m, n, and c, used in the reduction, are as follows:

Date.	m	n	c
	s.	s.	s.
May 19	−0.143	+0.184	+0.102
May 23	−0.046	+0.088	−0.114
May 24	−0.010	+0.082	−0.110
June 16	−0.113	+0.242	+0.050

From the clock-corrections obtained from the observations the following corrections and rates were computed by the method of least squares, and have been employed to determine the error of the clock at the time of the interchange of signals on each night:

Date.	Sidereal hour.	Correction.	Hourly rate.
		s. s.	s.
May 19	14.0	−0.594 ± 0.007	−0.034
May 23	16.0	+2.854 ± 0.010	−0.039
May 24	15.0	+2.117 ± 0.012	+0.016
June 16	17.0	−2.234 ± 0.007	−0.012

UNITED STATES LAKE-SURVEY, DETROIT, MICHIGAN.

The dates of the observations are May 19, 23, and 24, and June 1, 3, 10, 16, 26, and 29, 1871. The observer at Detroit was Mr. O. B. Wheeler, assistant United States lake-survey, and the instruments used were the Troughton and Simms transit of 43 inches focal length, clock No. 184, Bond & Son, and chronograph No. 216, Bond & Son.

The stone pier upon which the transit-instrument was mounted is situated 321.0 feet west and 294.0 feet north of the southwest corner of the stone foundation of the Westminster church, on Washington avenue.

The reductions have been made by Messrs. Thomas Russel, C. F. Burton, and John Eisenmann, subassistants United States lake-survey. A preliminary reduction by high and low stars of May 19, 23, and 24, was made by Mr. Burton. Two reductions by the method of least squares, on different suppositions, were made, either of which would cause an extreme range of only 0s.05 from the preliminary reduction.

For the remaining dates, the high and low star reductions were made by Mr. Eisenmann, and the least-square reductions by Mr. Russel. The agreement in extreme cases was the same as above.

In the following tables are contained the abbreviations:

C Δi = reduction to the middle wire;

Aberr = diurnal aberration;

B b = level-correction;

C c = collimation-correction;

t' = observed time of transit of a star, commonly the mean of five wires;

$t = t'$ the above corrections being made;

α = right ascension of a star;

$(\alpha - t)$ — (an assumed Δt) = the absolute term of the equations of condition;

a = deviation from the meridian, + when the instrument points east of south;

c = distance of the middle wire from the line of collimation;

ρ = hourly rate of the clock;

Δt = clock-correction, — when fast; + when slow.

NOTES.—On May 19, 23, and 24, $t = t'$, as above, except that the the collimation-correction is not included. On June 16, a = the deviation to be applied before the exchange of signals, and a' = that to be applied after the exchange of signals.

When $C\Delta i$ is omitted, t' = the mean of the several wires reduced to the middle wire.

Computation of clock-correction for Detroit, May 19, 1871.

Ill.	Star.	$C\Delta i$	Aberr.	Bb	t'	a	$(a-t)$	v
		s.	*s.*	*s.*	*h. m. s.*	*h. m. s.*	*s.*	*s.*
E.	Polaris, L. C	.....	+.58	+2.01	13 11 24.75	13 10 59.40	−27.94	.....
W.	Polaris, L. C	.....	+.58	−2.23	11 29.60	.....	28.55	.....
	ζ Virginis	+.03	−.01	+.06	28 39.41	28 08.37	31.12	+.02
	η Ursæ Majoris	+.05	−.02	+.15	42 59.87	42 29.05	31.00	−.22
	η Bootis	+.03	−.02	+.13	49 04.80	48 33.80	31.14	−.03
	τ Virginis	+.03	−.01	+.12	55 37.29	55 06.13	31.30	+.13
	ρ Bootis	+.04	−.02	+.25	14 26 48.85	14 26 17.67	31.45	+.17
W.	ε Bootis	+.03	−.02	+.20	39 53.85	39 22.66	31.40	+.09
E.	β Bootis	−.04	−.02	+.09	57 38.34	57 06.91	31.46	+.06
	β Libræ	−.03	−.01	+.05	15 10 36.60	15 10 05.42	31.19	−.17
	μ^1 Bootis	−.04	−.02	+.09	20 10.24	19 38.76	31.51	+.07
	α Serpentis	−.03	−.02	+.07	38 27.62	37 56.27	31.34	−.08
	ε Serpentis	−.03	−.01	+.07	44 55.94	44 24.62	31.35	−.12
	δ Ophiuchi	−.03	−.01	+.07	16 08 07.94	16 07 36.60	31.37	−.15
	ζ Ophiuchi	−.03	−.01	+.14	19 00 01.73	18 59 29.82	32.01	+.16
	ω Aquilæ	−.03	−.01	+.11	12 18.40	11 46.62	31.85	−.13
	γ Aquilæ	−.03	−.01	+.16	40 40.43	40 08.43	32.12	+.07
	α Aquilæ	−.03	−.01	+.15	45 02.14	44 30.15	32.10	+.03
E.	β Aquilæ	−.03	−.01	+.15	49 31.56	48 59.36	32.31	+.23

Normal equations.

$$+1965.223\,a + 3.671\,c + 167.496\,\rho + 70.250\,\delta\theta - 168.098 = 0$$
$$+3.671\,a + 3458.724\,c - 36.620\,\rho + 4.820\,\delta\theta + 31.768 = 0$$
$$7.496\,a - 36.620\,c + 104.196\,\rho + 2.170\,\delta\theta - 30.069 = 0$$
$$0.250\,a + 4.820\,c + 2.170\,\rho + 19.000\,\delta\theta + 3.510 = 0$$

$a = +0^s.09$

$c = -0^s.007$, lamp east.

$\rho = +0^s.1493$, rate per hour.

$\Delta t = -31^s.54.\ \pm 0^s.023$, at $15^h\ 57^m$.

Computation of clock-correction for Detroit, May 23, 1871.

Ill.	Star.	$C\Delta i$	Aberr.	Bb	t'	a	$(a-t)$	v
		s.	*s.*	*s.*	*h. m. s.*	*h. m. s.*	*s.*	*s.*
E.	Polaris, L. C	.....	+.58	−1.56	13 11 55.87	13 11 02.14	−52.75	.....
W.	Polaris, L. C	.....	+.58	−3.78	11 59.76	.....	54.42	.....
	ζ Virginis	+.03	−.01	+.12	28 50.01	28 08.36	41.79	−.15
	η Ursæ Majoris	+.05	−.02	+.30	43 10.32	42 29.00	41.65	+.03
	η Bootis	+.03	−.01	+.19	49 15.43	48 33.79	41.85	−.04
	τ Virginis	+.03	−.01	+.17	55 47.91	55 06.13	41.97	−.02
W.	α Bootis	+.03	−.01	+.26	14 10 29.69	14 09 47.92	42.05	+.10
E.	5 Ursæ Minoris	−.13	−.06	+.52	28 35.24	27 54.47	41.10	.....
	α^2 Libræ	−.03	−.01	+.08	44 28.17	43 46.09	42.12	−.13
	ψ Bootis	−.04	−.02	+.16	59 38.71	58 56.60	42.21	+.16
	β Libræ	−.03	−.01	+.08	15 10 47.54	15 10 05.45	42.13	−.14
	μ^1 Bootis	−.04	−.02	+.14	20 20.95	19 38.77	42.26	+.22
	α Coronæ Borealis	−.04	−.02	+.11	29 57.40	29 15.13	42.32	+.19
	α Serpentis	−.03	−.01	+.07	38 38.46	37 56.30	42.19	−.07
	ε Serpentis	−.03	−.01	+.07	45 06.77	44 24.65	42.15	−.14
	ε Coronæ Borealis	−.04	−.02	+.10	52 58.65	52 16.49	42.20	+.02
	d Sagittarii	−.03	−.02	+.11	19 10 49.10	19 10 06.29	42.87	−.03
	ω Aquilæ	−.03	−.01	+.18	12 29.52	11 46.73	42.93	+.17
E.	δ Aquilæ	−.03	−.01	+.16	19 43.29	19 00.63	42.78	−.04
W.	κ Aquilæ	+.03	−.01	+.13	30 40.48	29 58.00	42.63	−.24
	γ Aquilæ	+.03	−.01	+.17	40 51.03	40 08.54	42.68	−.12
	α Aquilæ	+.03	−.01	+.19	45 12.87	44 30.26	42.82	.00
W.	β Aquilæ	+.03	−.01	+.20	49 42.12	48 59.47	−42.87	+.03

Normal equations.

$$+1972.912\,a - 8.095\,c + 168.577\,\rho + 70.62\,\delta\theta + 802.347 = 0$$
$$-8.095\,a + 3477.516\,c - 3.731\,\rho + 6.26\,\delta\theta + 73.934 = 0$$
$$+168.577\,a - 3.731\,c + 131.784\,\rho + 44.713 = 0$$
$$+70.620\,a + 6.260\,c + 23.00\,\delta\theta + 51.740 = 0$$

$a = -0^s.38.$
$c = -0^s.02$, lamp east.
$\rho = +0^s.147$, rate per hour.
$\Delta t = -42^s.08. \pm 0^s.019$, at $16^h\,04^m$

Computation of clock-correction for Detroit, May 24, 1871.

Ill.	Star.	C Δ i	Aberr.	B b	t'	a	(a − t)	v
		s.	s.	s.	h. m. s.	h. m. s.	s.	s.
W.	Polaris, L. C		+.58	−3.78	13 12 01.85	13 11 02.74	−55.91	.....
E.	Polaris, L. C		+.58	−2.23	11 54.94	.....	50.55	.....
	ζ Virginis	−.03	−.01	+ .09	28 53.43	28 08.35	45.13	−.16
	η Bootis	−.03	−.02	+ .12	49 18.88	48 33.78	45.17	−.09
	α Bootis	−.03	−.02	+ .12	14 10 33.12	14 09 47.92	45.27	−.02
	ρ Bootis	−.04	−.02	+ .14	27 03.00	26 17.66	45.42	+.15
	ε Bootis	−.04	−.02	+ .14	40 07.97	39 22.66	45.39	+.08
E.	α^2 Libræ	−.03	−.01	+ .07	44 31.33	43 46.09	45.27	−.20
W.	β Bootis	+.04	−.02	+ .22	57 51.88	57 06.90	45.22	+.11
	β Libræ	+.03	−.01	+ .13	15 10 50.52	15 10 05.45	45.22	−.13
	μ^1 Bootis	+.04	−.02	+ .31	20 23.66	19 38.78	45.21	+.04
	α Coronæ Borealis	+.04	−.02	+ .31	30 00.16	29 15.14	45.35	+.10
	α Serpentis	+.03	−.01	+ .23	38 41.54	37 56.31	45.48	+.14
	ε Coronæ Borealis	+.04	−.02	+ .31	53 01.54	52 16.49	45.38	+.09
	β Scorpii	+.03	−.02	+ .14	58 43.04	57 57.84	45.35	−.12
	δ Ophiuchi	+.03	−.01	+ .20	16 08 21.86	16 07 36.65	45.43	+.01
	d Sagittarii	+.03	−.02	+ .07	19 10 51.83	19 10 06.32	45.59	−.18
W.	ω Aquilæ	+.03	−.01	+ .10	12 32.20	11 46.75	45.57	−.11
E.	γ Aquilæ	−.03	−.01	+ .08	40 54.43	40 08.57	45.90	+.04
	α Aquilæ	−.03	−.01	+ .08	45 16.21	44 30.29	45.96	+.08
E.	β Aquilæ	−.03	−.01	+ .07	49 45.57	48 59.50	−46.10	+.20

Normal equations.

$$+1967.037\,a - .0675\,c + 163.305\,\rho + 72.460\,\delta\theta + 519.956 = 0$$
$$-0.675\,a + 3458.511\,c + 11.019\,\rho - 1.480\,\delta\theta + 222.909 = 0$$
$$+163.305\,a + 11.019\,c + 101.074\,\rho + 32.893 = 0$$
$$+72.460\,a - 1.480\,c + 21.000\,\delta\theta + 24.870 = 0$$

$a = -0^s.26$
$c = -0^s.07$, lamp east.
$\rho = +0^s.098$, rate per hour.
$\Delta t = -45^s.28 \pm 0^s.020$, at $15^h\,54^m$

Carlin, Nevada, May 19, 1871.

Name of star.	Clamp.	T	b B	a A	c C	T'	AR.	ΔT
		h. m. s.	s.	s.	s.	h. m. s.	h. m. s.	m. s.
o Virginis	E.	11 53 46.09	+0.06	+ 9.70	−0.23	11 53 55.62	11 58 38.97	+4 43.35
ε Corvi	E.	58 29.58	+0.02	+ 17.65	−0.25	58 47.00	12 3 30.55	43.55
4 Draconis	E.	12 2 24.58	+0.12	− 55.78	−1.14	12 1 27.78	6 10.99	43.21
13 Comæ	E.	13 3.16	0.00	+ 4.95	−0.26	13 7.85	17 50.99	43.14
δ Corvi	E.	18 13.30	−0.04	+ 15.99	−0.24	18 29.01	23 12.86	43.85
β Corvi	E.	22 36.70	−0.07	+ 17.87	−0.25	22 54.25	27 37.80	43.55
21 Cassiopeæ, L. C.	W.	31 24.60	−0.20	+ 61.85	−0.85	32 25.20	37 7.33	42.13
32 Camelopardalis	W.	45 37.38	+0.56	−122.48	+2.22	43 37.68	48 20.57	42.89
θ Virginis	W.	58 20.47	+0.02	+ 13.21	+0.23	58 33.93	13 3 17.38	43.45
α Virginis	W.	13 13 26.94	+0.04	+ 14.61	+0.23	13 13 41.82	18 25.07	43.25
ζ Virginis	W.	23 12.64	+0.07	+ 12.01	+0.23	23 24.95	28 8.37	+4 43.42
Mean correction for $12^h\,40^m$ local sidereal time								+4 43.254
Excluding polar stars								+4 43.445

Normal equations.

$$0 = -2.51 + 11.00\,\delta T - 0.57\,a' + 1.28\,c \qquad \delta T = +0^s.254$$
$$0 = +18.44 - 0.57\,\delta T + 68.94\,a' + 62.19\,c \qquad a' = -0^s.058$$
$$0 = +35.55 + 1.28\,\delta T + 62.19\,a' + 140.36\,c \qquad c = -0^s.230$$

(To avoid large numbers, an azimuth of $+18^s.50$ was introduced: a', found by the method of least squares, gives the correction of the adopted azimuth; therefore, $a = +18^s.442$.)

Carlin, Nevada, May 23, 1871.

Name of star.	Clamp.	T	*b* B	*a* A	*c* C	T′	AR.	Δ T
		h. m. s.	*s.*	*s.*	*s.*	*h. m. s.*	*h. m. s.*	*m. s.*
ζ Ophiuchi	E.	16 25 20.82	−0.02	+ 4.46	−0.01	16 25 25.25	16 30 4.89	+4 39.64
η Herculis	W.	33 49.96	−0.22	+ 0.20	+0.02	33 49.96	38 30.22	40.26
ι Ophiuchi	W.	43 12.84	−0.17	+ 2.90	+0.01	43 15.58	47 55.84	40.26
κ Ophiuchi	W.	46 52.46	−0.18	+ 2.96	+0.01	46 55.25	51 35.16	39.91
ε Ursæ Minoris	W.	55 14.38	−0.72	−27.78	+0.08	54 45.96	59 25.94	39.98
α Herculis	W.	17 4 4.77	−0.15	+ 2.58	+0.01	17 4 7.21	17 8 47.38	40.17
ω Draconis	E.	33 13.82	−0.63	− 7.35	−0.03	33 5.81	37 46.01	+4 40.20
Mean correction for 17h 0m local sidereal time								+4 40.060

Normal equations.

$$0 = -1.90 + 7.00\,\delta T - 3.90\,a' - 7.97\,c \qquad \delta T = +0^s.060$$
$$0 = +10.25 - 3.90\,\delta T + 27.26\,a' + 32.16\,c \qquad a' = -0.353$$
$$0 = +12.66 - 7.97\,\delta T + 32.16\,a' + 68.53\,c \qquad c = -0.012$$

I introduced a preliminary azimuth of + 6s.00; the azimuth of the instrument was + 5s.647. The observations of η Draconis and ω Draconis differ so much that they had to be excluded.

Carlin, Nevada, May 24, 1871.

Name of star.	Clamp.	T	*b* B	*a* A	*c* C	T′	AR.	Δ T
		h. m. s.	*s.*	*s.*	*s.*	*h. m. s.*	*h. m. s.*	*m. s.*
γ Cephei, L. C	E.	11 29 21.72	+1.22	−4.18	+1.32	11 29 20.08	11 34 2.59	+4 42.51
β Leonis	E.	37 49.86	−0.55	−0.48	−0.31	37 48.52	43 29.27	40.75
γ Ursæ Majoris	E.	42 23.65	−0.97	+0.44	−0.52	42 22.60	47 3.00	40.40
o Virginis	E.	53 59.94	−0.48	−0.57	−0.30	53 58.59	58 38.92	40.33
4 Draconis	E.	12 1 30.32	−1.84	+3.23	−1.48	12 1 30.23	12 6 10.58	40.35
β Corvi	E.	22 58.86	−0.24	−1.04	−0.32	22 57.26	27 37.76	40.50
21 Cassiopeæ, L. C.	W.	32 31.19	+0.34	−3.57	−1.11	32 26.85	37 6.05	39.20
32 Camelopardalis	W.	43 30.87	−2.68	+7.10	+2.90	43 38.19	48 19.81	41.62
θ Virginis	W.	58 37.92	−0.24	−0.77	+0.30	58 37.21	13 3 17.36	40.15
α Virginis	W.	13 13 45.64	−0.15	−0.85	+0.31	13 13 44.95	18 25.05	+4 40.10
Mean correction of chronometer excluding the polar stars, for 13h 0m local sidereal time								+4 40.372

Normal equations.

$$0 = +4.22 + 10.00\,\delta t + 0.63\,a$$
$$0 = -89.14 + 0.63\,\delta t + 82.97\,a \qquad a = -1^s.072$$

Several other computations have been made, giving for the correction of chronometer no better result. The error of collimation was adopted to − 0s.30.

Carlin, Nevada, May 24, 1871.

Name of star.	Clamp.	T	*b* B	*a* A	*c* C	T′	AR.	Δ T
		h. m. s.	*s.*	*s.*	*s.*	*h. m. s.*	*h. m. s.*	*m.*
ε Serpentis	W.	15 40 45.54	−0.06	−1.25	+0.30	15 40 44.53	15 44 24.65	+4 40.12
ζ Ursæ Minoris	W.	44 1.61	−0 19	+6.32	+1.47	44 9.21	48 49.34	40.13
β¹ Scorpii	W.	53 19.06	−0.01	−1.95	+0.32	53 17.42	57 57 84	40.42
δ Ophiuchi	W.	16 2 57.60	0.00	−1.48	+0.30	16 2 56.42	16 7 36.65	40.23
τ Herculis	E.	11 14.00	−0.17	+0.32	−0.44	11 13.71	15 53.70	39.99
η Draconis	E.	17 36.72	−0.24	+1.61	−0.64	17 37.45	22 17.79	40.34
ζ Ophiuchi	E.	25 26.92	−0.07	−1.67	−0.30	25 24.88	30 4.89	40.01
η Herculis	E.	33 51.10	−0.13	−0.07	−0 39	33 50.51	38 30.22	+4 39.71
Mean correction for 16h 10m								+4 40.12

Normal equations.

$$0 = -2.78 + 8.00\,\delta t - 0.86\,a \qquad \delta t = +0^s.120$$
$$0 = +24.99 - 0.86\,\delta t + 11.74\,a \qquad a = -2^s.120$$

The error of collimation of the instrument is adopted as −0s.30.

The following table contains the corrections of the chronometer and its rate, to obtain the correction for the time of exchange:

Date.	Local sidereal time.	Corrections of chronometer.	Hourly rate.
	h.	m. s.	s.
May 19, 1871	12.667	+ 4 43.445	− 0.034
May 23, 1871	17.000	+ 4 40.060	+ 0.009
May 24, 1871	14.502	+ 4 40.246	+ 0.009

For exchange, mean-solar-time chronometer Hutton No. 288 was always used. May 19, I find in the proper place only one comparison of Negus 1344 with Hutton 288:

	h.	m.	s.	h.	m.	s.
Negus...1344	13	30	20 0	13	33	27.0
Hutton.. 288	9	21	20.0	9	24	26.5

Hutton 288, at $9^h\ 22^m\ 53^s.25$, is slow of local sidereal time $4^h\ 13^m\ 43^s.666$. In another place I find one comparison made May 19, in the morning, and one at nearly the same time May 20:

	May 19.			*May* 20.					
	h.	m.	s.	h.	m.	s.	h.	m.	s.
Negus...	0	32	12.0	1	41	31.0	1	44	34.0
Hutton..	20	25	21.50	21	30	29.5	21	33	32.0

Therefore, I find the rate of Hutton 288 from the morning to the evening of May 19, + $9^s.9785$, and from the evening to the next morning, + $9^s.9641$, both for one hour of Hutton 288. To reduce Hutton for the time of exchange, the mean + $9^s.9713$ is used.

For May 23 and May 24, one comparison was made before and after exchange.

May 23.

	h.	m.	s.	h.	m.	s.	h.	m.	s.
Negus...1344	13	27	18.0	13	30	25.0	13	33	34.0
Hutton.. 288	9	2	24.5	9	5	31.0	9	8	39.5

And after exchange:

	h.	m.	s.	h.	m.	s.
Negus...1344	16	12	10.0	16	15	15.0
Hutton.. 288	11	46	49.5	11	49	54.0

May 24.

	h.	m.	s.	h.	m.	s.
Negus...1344	13	34	32.0	13	37	35.0
Hutton.. 280	9	5	37.5	9	8	40.0

After exchange:

	h.	m.	s.	h.	m.	s.
Negus...1344	15	30	19.0	15	33	20.0
Hutton.. 288	11	1	5.5	11	4	6.0

From these comparisons and the rate given for Negus 1344, the following table for Hutton 288 is derived:

Date.	Hours on the face of Hutton's chronometer.	Hutton 288 behind local sidereal time.	Losing per hour on face of Hutton's chronometer.	Logarithm.
	h. m. s.	h. m. s.	s.	
May 19, 1871	9 22 53.25	4 13 43.666	9.9713	0.9987518
May 23, 1871	10 26 56.72	4 29 47.454	9.8478	0.9933402
May 24, 1871	10 4 52.25	4 33 44.496	9.8632	0.9946986

The logarithm is used to convert the chronometer-time of the means of the signals into sidereal time.

EXCHANGE OF SIGNALS.

Signals sent from the Washington Observatory.

On the 19th of May the first signals to Carlin were at intervals of one second, and were sent by so arranging the apparatus that the clock *broke* a *closed* circuit at each second. These signals could not be used at Carlin.

Afterward an attempt was made to send signals by causing the clock to *close* an *open* circuit, but these signals failed to get through.

So much objection was made at Carlin to the clock-signals that signals were sent, finally, at intervals of ten seconds, with an ordinary message-key, by breaking the circuit in coincidence with the beat of the clock as indicated by the sounder in the local circuit.

Similar signals were sent on the 23d and 24th of May.

On the 16th of June signals were sent, at intervals of ten seconds, directly from the clock, by switching the clock into the main line at the proper time to enable it to break the circuit at the desired second.

Signals sent to the Observatory.

Signals from Carlin and Austin were received on the Observatory chronograph.

Exchange of signals between Washington, D. C., Detroit, Mich., and Carlin, Nev.

MAY 19, 1871.—*Signals sent from Washington.*

Washington clock.			Detroit clock.			Carlin chronometer.			Washington clock.			Detroit clock.			Carlin chronometer.		
h.	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*
17	35	0.00	17	11	30.75	10	44	45.20	17	37	30.00	17	14	0.90	10	47	15.0
		10.00			40.70			55.40			40.00			10.82			24.9
		20.00			50.77		45	5.30			50.00			20.85			34.9
										38	0.00			30.80			45.0
	36	0.00		12	30.77		45	45.60			10.00			40.82			55.0
		10.00			40.83			55.10			20.00			50.81		48	4.9
		20.00			50.86		46	5.60			30.00		15	0.82			14.9
		30.00		13	0.89			15.20									
		40.00			10.91			25.10	Mean,	17	36	52.94	17	13	23.78	10	46	3.8
		50.00			20.90			35.20									
	37	0.00			30.86			44.90									

MAY 23, 1871.—*Signals sent from Washington.*

Washington clock.			Detroit clock.			Carlin chronometer.			Washington clock.			Detroit clock.			Carlin chronometer.		
h.	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*
18	35	0.00	18	11	45.19	11	28	48.30	18	37	50.00	18	14	35.11	11	31	3.9
		10.00			55.28			58.60		38	0.00			45.05			47.9
		20.00		12	5.23		29	8.50									
		30.00			15.27			18.50		39	0.00		15	45.18		32	47.7
		40.00			25.20			28.40			10.00			55.18			57.6
		50.00			35.19			38.40			20.00		16	5.00		33	7.6
	36	0.00			44.99			48.10			30.00			15.00			17.6
											40.00			25.00			27.6
	37	0.00		13	45.05		30	48.10			50.00			35.00			37.6
		10.00			55.80			58.60		40	0.00			45.20			47.6
		20.00		14	5.16		31	8.00									
		30.00			15.11			17.90	Mean,	18	37	30.00	18	14	15.15	11	31	18.0
		40.00			25.05			28.00									

MAY 23, 1871.—*Signals sent from Carlin.*

FIRST SERIES.

Washington clock.			Detroit clock.			Carlin chronometer.			Washington clock.			Detroit clock.			Carlin chronometer.		
h.	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*
17	53	.....	17	29	.....	10	47	.....		17	55	46.20	17	32	30.90	10	49	40.00
		15.80		30	0.52			10.00			51.20			35.80			45.00
		21.20			5 84			15.00			56.50			41.20			50.00
		25.80			10.49			20.00		56	1.50			46.20			55.00
		30.90			15.69			25.00			6.30			51.00		50	0.00
		35.90			20.60			30.00									
		40.80			25.52			35.00		57	6.50		33	51.18		51	0.00
		45.90			30.59			40.00			11.50			56.20			5.00
		50.90			35.61			45.00			16.50		34	1.20			10.00
		55.90			40.61			50.00			21.60			6.40			15.00
	54	1.00			45.69			55.00			26.50			11.30			20.00
		6.00			50.70		48	0.00			31.40			16.18			25.00
		.....			.....			.....			36.50			21.25			30.00
											41.40			26.00			35.00
	55	6.10		31	51.05		49	0.00			46.60			31.40			40.00
		11.20			56.05			5.00			51.60			36.39			45.00
		16.20		32	1.00			10.00			56.50			41.22			50.00
		21.30			6.00			15.00		58	1.70			46.40			55.00
		26.30			11.05			20.00			6.60			51.35		52	0.00
		31.50			16.15			25.00									
		36.40			21.10			30.00	Mean,	17	55	44.24	17	32	28.97	10	49	37.97
		41.30			26.00			35.00										

MAY 23, 1871.—*Signals sent from Carlin.*

SECOND SERIES.

Washington clock.			Detroit clock.			Carlin chronometer.			Washington clock.			Detroit clock.			Carlin chronometer.		
h.	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*
18	26	11.20	18	2	56.00	11	20	0.00		18	28	56.80	18	5	41.63	11	22	45.00
		16.20		3	1.00			5.00			29	1.70			46.21			50.00
		21.20			5.99			10.00				6.80			51.61			55.00
		26.20			11.00			15.00				11.60			56.41		23	0.00
		31.30			16.00			20.00				16.70		6	1.49			5.00
		36.20			21.00			25.00				21.60			6.39			10.00
		41.10			25.92			30.00				26.80			11.58			15.00
		46.40			31.28			35.00				31.60			16.45			20.00
		51.50			36.33			40.00				36.70			21.48			25.00
		56.40			41.17			45.00				41.70			26.51			30.00
	27	1.60			46.40			50.00				46.80			31.60			35.00
		6.30			51.00			55.00				51.80			36.64			40.00
		11.30			56.12		21	0.00				56.80			41.67			45.00
		16.50		4	1.50			5.00			30	2.00			46.80			50.00
		26.50			11.30			15.00				6.70			51.59			55.00
		31.40			16.25			20.00				11.80			56.70		24	0.00
		36.40			21.29			25.00				16.90		7	1.80			5.00
		41.30			26.00			30.00				21.70			6.50			10.00
		46.60			31.40			35.00				26.90			11.78			15.00
		51.80			36.60			40.00				32.00			16.80			20.00
	28	1.60			46.40			50.00				36.90			21.70			25.00
		6.50			51.26			55.00				41.90			26.70			30.00
		11.40			56.12		22	0.00				47.00			31.80			35.00
		16.50		5	1.29			5.00				52.20			37.00			40.00
		21.40			6.29			10.00				57.10			41.89			45.00
		26.40			11.29			15.00			31	2.30			47.18			50.00
		31.50			16.37			20.00				7.20			52.05			55.00
		36.50			21.27			25.00				12.10			56.95		25	0.00
		41.60			26.60			30.00										
		46.60			31.61			35.00	Mean,	18	28	43.92	18	5	22.56	11	22	32.12
		51.60			36.69			40.00										

MAY 24, 1871.—*Signals sent from Washington.*

FIRST SERIES.

Washington clock.			Detroit clock.			Carlin chronometer.			Washington clock.			Detroit clock.			Carlin chronometer.		
h.	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*
16	..	.....	16	..	.....	9	..	.....	16	56	50.00	16	33	37.60	9	46	54.10
		.....			.....			.....		57	0.00			47.80		47	4.20
		.....			.....			.....									
		.....			.....			.....		58	0.00		34	47.82		48	4.20
	54	30.00		31	17.90		44	34.30			10.00			57.76			13.90
		40.00			28.00			45.50			20.00		35	7.70			23.70
		50.00			37.69			54.20			30.00			17.69			33.60
											40.00			27.54			43.40
	56	.....		32	.....		46	.....			50.00			37.89			53.80
		.....			.....			.....		59	0.00			47.89		49	3.80
		.....		33	.....			.....									
		30.00			17.70			34.00	Mean, 16	57	10.71	16	33	58.47	9	47	14.76
		40.00			27.65			43.90									

SECOND SERIES.

Washington clock.			Detroit clock.			Carlin chronometer.			Washington clock.			Detroit clock.			Carlin chronometer.		
h.	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*
17	1	.....	16	37	.....	9	51	.....	17	4	.....	16	40	47.86	9	54	3.00
				38	.....			.....			10.00			57.80			12.80
		30.00			17.70			33.20									
		40.00			27.70			43.00		5	10.00		41	57.89		55	12.70
		50.00			37.79			53.30			20.00		42	7.79			22.60
	2	0.00			47.85		52	3.20			30.00			17.70			32.60
		10.00			57.89			13.20			.....			.....			.....
											50.00			37.71			52.60
	3	10.00		39	57.89		53	13.10		6	0.00			47.71		56	2.60
		20.00		40	7.62			22.30			10.00			57.90			12.60
		30.00			17.60			32.80									
		40.00			27.70			42.80	Mean, 17	3	49.44	16	40	37.21	9	53	52.33
		50.00			37.76			53.00									

THIRD SERIES.

Washington clock.			Detroit clock.			Carlin chronometer.			Washington clock.			Detroit clock.			Carlin chronometer.		
h.	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*
17	26	0.00	17	2	48.00	10	15	59.60	17	26	40.00	17	3	27.93	10	16	39.50
		10.00			57.90		16	9.30			50.00			37.80			49.10
		20.00		3	7.68			19.20									
		30.00			17.85			29.30	Mean, 17	26	25.00	17	3	12.86	10	16	24.33

MAY 24, 1871.—*Signals sent from Carlin.*

FIRST SERIES.

Washington clock.			Detroit clock.			Carlin chronometer.			Washington clock.			Detroit clock.			Carlin chronometer.		
h.	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*
17	9	59.30	16	46	46.55	10	0	0.00		17	12	39.70	16	49	27.00	10	2	40.00
	10	4.40			51.70			5.00				44.90			32.28			45.00
		9.30			56.65			10.00				49.70			37.10			50.00
		14.40		47	1.70			15.00				54.80			42.15			55.00
		19.40			6.69			20.00				59.80			47.15		3	0.00
		24.50			11.81			25.00			13	4.90			52.20			5.00
		29.40			16.71			30.00				9.80			57.13			10.00
		34.20			21.51			35.00				14.80		50	2.10			15.00
		39.60			26.90			40.00				19.80			7.05			20.00
		44.70			32.00			45.00				24.80			12.10			25.00
		49.50			36.80			50.00				29.80			17.15			30.00
		54.50			41.88			55.00				35.10			22.45			35.00
		59.70			46.90		1	0.00				39.90			27.15			40.00
	11	4.60			51.91			5.00				44.90			32.15			45.00
		9.50			56.80			10.00				50.00			37.30			50.00
		14.60		48	1.90			15.00				54.10			42.39			55.00
		19.70			7.00			20.00				59.90			47.20		4	0.00
		24.70			12.00			25.00			14	5.00			52.21			5.00
		29.70			16.98			30.00				9.90			57.10			10.00
		34.60			21.92			35.00				15.10		51	2.30			15.00
		39.80			26.98			40.00				19.80			7.10			20.00
		44.60			31.87			45.00				24.90			12.15			25.00
		49.80			37.10			50.00				29.80			17.15			30.00
		54.80			42.00			55.00				35.20			22.50			35.00
		59.70			47.00		2	0.00				40.20			27.50			40.00
	12	4.70			52.00			5.00				45.10			32.38			45.00
		9.70			57.00			10.00				50.40			37.30			50.00
		.....		49	.....			.....				55.10			42.39			55.00
		19.80			7.00			20.00			15	0.10			47.21		5	0.00
		24.70			11.95			25.00										
		29.70			16.99			30.00	Mean,	17	12	30.06	16	49	17.29	10	2	30.25
		34.70			21.99			35.00										

SECOND SERIES.

Washington clock.			Detroit clock.			Carlin chronometer.			Washington clock.			Detroit clock.			Carlin chronometer.		
h.	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*
17	17	0.50	16	53	47.89	10	7	0.00		17	19	40.90	16	56	28.18	10	9	40.00
		5.70			52.81			5.00				46.00			33.21			45.00
		10.30			57.56			10.00				51.00			38.29			50.00
		15.50		54	2.79			15.00				56.00			43.30			55.00
		20.50			7.80			20.00			20	0.90			48.15		10	0.00
		25.30			12.53			25.00				5.90			53.19			5.00
		30.60			17.80			30.00				11.00			58.19			10.00
		35.30			22.61			35.00				16.10		57	3.33			15.00
		40.70			28.00			40.00				21.00			8.30			20.00
		45.70			33.00			45.00				26.00			13.70			25.00
		50.60			37.91			50.00				31.10			18.50			30.00
		55.70			42.90			55.00				36.10			23.55			35.00
	18	0.60			47.90		8	0.00				41.20			28.60			40.00
		5.60			53.10			5.00				46.10			33.49			45.00
		10.40			57.70			10.00				51.50			38.59			50.00
		.....		55	.....			.....				56.20			43.70			55.00
		.....			.....			.....			21	1.20			48.50		11	0.00
		25.70			12.88			25.00				6.20			53.52			5.00
		30.50			17.79			30.00				11.20			58.50			10.00
		35.60			22.90			35.00				16.20		58	3.50			15.00
		40.70			28.05			40.00				21.10			8.36			20.00
		45.70			33.00			45.00				26.40			13.72			25.00
		50.80			38.10			50.00				31.20			18.50			30.00
		55.80			43.10			55.00				.....			.....			.....
	19	0.80			48.10		9	0.00				41.30			28.60			40.00
		5.80			53.10			5.00				46.20			33.48			45.00
		.....			.....			.....				51.30			38.59			50.00
		.....		56	.....			.....				56.40			43.70			55.00
		20.90			8.19			20.00			22	1.30			48.60		12	0.00
		25.90			13.20			25.00										
		30.90			18.10			30.00	Mean,	17	19	31.88	16	56	19.00	10	9	30.98
		36.00			23.22			35.00										

May 23, 1871, I find one more set sent from Washington to Carlin, but not recorded at Detroit:

h.	m.	s.	h.	m.	s.	h.	m.	s.	h.	m.	s.		h.	m.	s.	h.	m.	s.
17	21	10.00	10	15	10.80	17	47	.....	10	41	.....			17	49	30.00	10	43	26.0
		20.00			20.80			40.00			36.10					40.00			25.9
		.....			.....			50.00			46.30					50.00			45.9
		40.00			40.40		48	0.00			56.20				50	0.00			55.8
		50.00			50.30			10.00		42	6.20					10.00		44	5.8
	22	0.00		16	0.20			20.00			16.20					20.00			15.7
								30.00			26.10					.....			.....
													Mean,	17	40	56.47	10	34	53.1

And one set sent from Carlin to Washington, on the same date recorded only at Washington and Carlin:

h.	m.	s.	h.	m.	s.		h.	m.	s.	h.	m.	s.
18	1	37.40	10	55	30.00		18	3	7.80	10	57	0 00
		42.30			35.00				17.60			10.00
		47.30			40.00				22.70			15.00
		57.20			50.00				27.60			20.00
	2	2.40			55.00				32.60			25.00
		7.30		56	0.00				37.40			30.00
		12.80			5.00				42.60			35.00
		17.60			10.00				47.50			40.00
		22.70			15.00				52.60			45.00
		27.50			20.00				57.80			50.00
		32.30			25.00			4	7.60		58	0.00
		37.50			30.00							
						Mean,	18	2	51.22	10	56	43.70

Deduction of the results for longitude.

Date.	Signals sent from—	Washington clock.	Correction of Washington clock.	Local sidereal time of the mean of the signals.	Detroit clock.	Correction of Detroit clock.	Local sidereal time of the mean of the signals.	Carlin chronometer.	Correction of the Carlin chronometer.	Local sidereal time of the mean of the signals.	Carlin west of—		Double-wave time for Carlin.		Final difference of longitude: Carlin west of—		Longitude of Detroit.
											Washington.	Detroit.	Washington.	Detroit.	Washington.	Detroit.	
1871.		h. m. s.	s.	h. m. s.	h. m. s.	s.	h. m. s.	h. m. s.	h. m. s.	h. m. s.	h. m. s.	h. m. s.	s.	s.	h. m. s.	h. m. s.	h. m.
May 19	W. to C.	17 36 52.94	−0.72	17 36 52.22	17 13 23.78	−31.73	17 12 52.05	10 46 38.06	+4 13 57.58	15 0 35.64	2 36 16.58	2 12 16.41	[1.30]	[0.77]	2 36 17.23	2 12 16.8	0 24 0.43
May 23	W. to C.	17 40 56.47	+2.79	17 40 59.26	.....	.....	.....	10 34 53.81	+4 29 48.76	15 4 42.57	16.69	.....	.....	.....	.....	.....	.....
May 23	W. to C.	18 37 30.00	+2.75	18 37 32.75	18 14 15.15	−42.40	18 13 32.75	11 31 18.02	58.02	16 1 16.04	16.71	16.71	.....	.....	.....	.....	.....
May 23	C. to W.	17 55 44.24	+2.78	17 55 47.02	17 32 28.97	−42.30	17 31 46.67	10 49 37.97	51.18	15 19 29.15	17.87	17.52	.....	.....	.....	.....	.....
May 23	C. to W.	18 2 51.22	+2.78	18 2 54.00	.....	.....	.....	10 56 43.70	52.34	15 26 36.04	17.96	.....	.....	.....	.....	.....	.....
May 23	C. to W.	18 28 43.92	+2.76	18 28 46.68	18 5 28.58	−42.38	18 4 46.20	11 22 32.12	56.58	15 52 28.70	17.98	17.50	1.24	0.80	17.32	17.11	0.21
May 24	W. to C.	16 57 10.71	+2.15	16 57 12.86	16 33 58.47	−45.35	16 33 13.12	9 47 14.76	+4 33 41.59	14 20 56.35	16.51	16.77	.....	.....	.....	.....	.....
May 24	W. to C.	17 3 49.44	+2.15	17 3 51.59	16 40 37.21	−45.36	16 39 51.85	9 53 52.33	42.68	14 27 35.01	16.58	16.84	.....	.....	.....	.....	.....
May 24	W. to C.	17 26 25.00	+2.16	17 26 27.16	17 3 12.86	−45.39	17 2 27.47	10 16 24.33	46.40	14 50 10.73	16.43	16.74	.....	.....	.....	.....	.....
May 24	C. to W.	17 12 30.06	+2.15	17 12 32.21	16 49 17.29	−45.37	16 48 31.92	10 2 30.25	44.01	14 36 14.26	17.95	17.66	.....	.....	.....	.....	.....
May 24	C. to W.	17 19 31.88	+2.15	17 19 34.03	16 56 19.00	−45.38	16 55 33.62	10 9 30.98	45.26	14 43 16.24	17.79	17.38	1.36	0.74	17.19	17.15	0.04

	h. m.	s.	s.
Carlin west of Washington	2 36	17.25	±0.026
Carlin west of Detroit	2 12	17.02	±0.075
Detroit west of Washington	0 24	0.23	±0.076

Mean places of stars for 1871.0 *used for determination of latitude of Carlin, Nevada.*

No. of pair.	No. in B. A. C.	Declination.	No. of pair.	No. in B. A. C.	Declination.	No. of pair.	No. in B. A. C.	Declination.
		° ′ ″			° ′ ″			° ′ ″
	4526	25 1 2.73		4825	37 11 39.22		5234	18 38 30.7
1	4540	56 0 36.66	6	4841	44 11 57.58	11	5249	62 59 56.(
	4568	55 20 5.00		4885	42 55 27.50		5322	23 9 52.3
2	4594	26 21 2.56	7	4897	38 20 36.56	12	5348	58 54 37.1
	4640	29 17 1.25		4952	47 47 15.90		5385	36 49 12.(
3	4684	51 35 32.39	8	5000	33 34 10.00	13	5400	44 9 52.7
	4728	42 7 33.27		5071	.....		5432	34 11 14.(
4	4758	39 23 16.50	9	5098	.....	14	5463	46 37 18.(
	4804	50 25 22.70		5116	62 43 17.93			
5	4808	30 56 20.26	10	5146	18 5 14.96			

Observations for latitude.—Station, Carlin, Nevada.

Date.	No. of star.	Micrometer readings.	Level. N.	Level. S.	Remarks.
1871.					
May 17	4568	12 52.2	13.5	10.0	
	4594	24 66.3	8.0	15.0	
	4640	7 94.7	11.0	12.5	
	4684	31 72.6	15.0	8.3	
	4804	17 35.8	9.8	14.0	
	4808	15 25.6	14.8	9.2	
25	4568	12 92.7	17.2	13.0	
	4594	25 8.0	12.4	18.0	
	4640	7 53.0	14.8	15.3	
	4684	31 30.9	17.0	13.9	
	4728	19 16.9	15.0	18.0	Mistake in reading, to be excluded.
	4758	23 16.7	16.8	15.0	
	4804	18 32.0	16.0	16.2	
	4808	16 8.2	13.2	18.8	
26	4526	11 73.6	17.0	10.0	
	4540	28 74.9	12.4	14.7	
	4568	9 59.0	14.2	12.8	
	4594	21 83.2	15.7	12.5	
	4640	1 45.3	14.8	14.0	
	4684	25 26.9	12.8	16.3	
	4728	16 20.4	13.0	16.0	
	4758	20 65.7	16.0	13.9	
	4804	17 52.5	9.8	21.0	
	4808	15 20.8	19.0	11.8	
	4825	11 91.2	7.2	23.5	
	4841	12 88.3	21.3	9.6	
	4885	25 6.7	16.2	15.0	
	4897	18 53.5	11.3	20.2	
	4952	15 66.2	9.2	19.8	
	5000	12 99.2	16.9	11.7	
	5071	1 62.5	13.0	15.2	
	5098	26 51.6	13.0	15.4	
	5116	33 23.9	17.8	10.5	
	5146	6 18.7	9.0	19.2	
	5234	20 74.2	17.8	11.2	
	5249	15 20.0	9.7	19.8	

Date.	No. of star.	Micrometer readings.	Level. N.	Level. S.	Remarks.
1871.					
May 26	5322	32 51.6	13.8	16.4	
	5348	3 15.4	15.7	13.9	
	5385	9 64.8	13.2	16.2	
	5400	28 88.7	13.8	15.2	
	5432	4 41.7	16.2	13.2	
	5463	36 62.2	7.8	20.8	Must be 31ˢ.
27	4526	6 99.8	22.2	16.2	
	4540	24 6.0	17.8	20.5	
	4568	10 9.2	21.2	16.8	
	4594	22 22.8	15.8	22.7	
	4640	3 18.5	16.0	23.0	
	4684	27 8.0	20.0	19.5	
	4728	10 16.9	18.8	20.7	
	4758	13 78.9	17.5	22.0	Must be 14ˢ 58ᵈ.
	4804	13 22.2	18.0	22.0	
	4808	10 87.7	18.2	21.8	
	4825	14 9.3	19.0	21.2	
	4841	15 12.8	17.0	23.3	
	4885	19 69.4	18.8	22.0	Very faint.
	4897	13 5.0	17.6	23.0	
	4952	11 30.0	20.9	20.0	
	5000	8 52.9	13.7	....	Bubble beyo scale.
	5071	2 76.9	5.0	10.2	
	5098	27 51.0	2.3	13.0	
	5116	30 6.0	22.8	18.8	Mistake in read excluded.
	5146	3 54.7	20.7	21.3	
	5234	14 97.8	13.8	10.8	
	5249	9 75.9	0.0	21.0	Must be 9ˢ 45ᵈ.(
	5322	32 87.0	12.0	9.8	
	5348	3 58.3	11.2	10.8	
	5385	5 11.1	18 3	15.7	
	5400	24 37.4	13.2	20.7	
	5432	4 36.0	14.0	23.0	
	5463	31 48.1	21.0	16.2	

Computations for latitude of Carlin, Nevada.

Date.	No. of pair.	Half-sum of declination.	Corrections.			Latitude.
			Micr. and ref.	Level.	Merid.	
1871.		° ′ ″	′ ″	″		° ′ ″
May 17	2	40 50 37.68	− 8 11.00	− 2.36	.....	40 42 24.32
	3	26 19.97	+16 1.70	+ 3.51	.....	25.18
	5	40 53.23	+ 1 25.00	+ 0 95	.....	19.18
May 25	2	40 50 39.29	− 8 11.49	− 0.95	.....	40 42 26.85
	3	26 21.67	+16 1.69	+ 1.76	.....	25.12
	4	45 29.14	− 2 61.68	− 0.81	.....	[26.36]
	5	40 55.10	+ 1 30.50	− 3.92	.....	21.68
May 26	1	40 30 55.63	+11 28.04	+ 3.17	.....	40 42 26.84
	2	50 39.48	− 8 15.08	+ 3.10	.....	27.50
	3	26 21.88	+16 3.18	− 1.82	.....	23.24
	4	45 29.37	− 3 0.08	− 0.61	.....	28.68
	5	40 55.33	+ 1 33.70	− 2.70	.....	26.33
	6	41 52.30	+ 0 39.26	− 3.10	.....	28.46
	7	38 5.52	+ 4 24.16	− 5.20	.....	24.48
	8	40 44.81	+ 1 47.97	− 3.65	.....	29.13
	9	59 17.83	−16 46.65	− 3.10	.....	28.08
	10	24 17.32	+18 14.08	− 1.28	.....	30.12
	11	46 13.38	− 3 44.13	− 2.36	.....	26.89
	12	62 14.01	− 19 47.47	− 0.27	.....	26.27
	13	29 31.73	+12 58.04	− 2.97	.....	26.80
	14	24 14.68	+18 20.25	− 6.75	.....	28.18
May 27	1	40 30 55.82	+11 30.02	+ 2.23	.....	40 42 28.07
	2	50 39.69	− 8 10.80	− 1.69	.....	27.20
	3	26 22.09	+16 6.37	− 4.39	.....	24.07
	4	45 29.61	− 2 58.75	− 4.32	.....	26.54
	5	40 55.56	+ 1 34.83	− 5.13	.....	25.26
	6	41 52.57	+ 0 41.85	− 5.74	.....	28.68
	7	38 5.77	+ 4 28.69	− 5.80	.....	28.66
	8	40 45.05	+ 1 52.05	− 8.50	.....	28.60
	9	59 18.07	−16 40.59	−10.73	.....	26.75
	10	24 17.55	−18 12.51	+ 2.30	.....	[32.36]
	11	46 13.54	− 3 43.24	− 5.40	.....	24.90
	12	62 14.30	−19 44.44	+ 1.76	.....	31.62
	13	29 32.00	+12 59.01	− 3.31	.....	27.70
	14	24 14.94	+18 16.85	− 2.83	.....	28.96

Mean, 40° 42′ 26″.67 ± 0″.28.

We conclude, therefore, that the longitude of Carlin station is 39° 04′ 18″.80 west of Washington, or 116° 07′ 20″.6 west of Greenwich, and the latitude = N. 40° 42′ 26″.67.

BATTLE MOUNTAIN, NEVADA.

Geographical position of station: Longitude, 116° 56′ 13″.50; latitude, 40° 38′ 18″.74 ±0″.21.

The astronomical station is situated near Battle Mountain, Nev., a town on the Central Pacific Railroad. The track of the railroad runs at this point in a nearly north and south direction. The astronomical monument is placed southeastward from the town, and 1,475 feet east of the track, and 1,166 feet from the public-school building. Battle Mountain has about 800 inhabitants. The astronomical station is but slightly elevated above the railroad-track; the place is level, but at a distance of one mile prominent hills and ridges, rising 3,000 feet above the station, are visible. The elevation of the station is determined to be, approximately, 4,500 feet above the level of the sea.

Meteorological conditions.—No detailed meteorological observations were taken at this station. From the diary of the observer it can be seen that it was cloudy almost always during the day, but clear at night. The observer lost much time waiting for the line to Detroit. On some

days only very few observations for latitude were taken, after he had waited until late at night expecting to get the use of the wires for longitude-work.

Description of observatory and instruments used.—The construction of the observatory was the same as at Carlin, and a description of it will be found in the report for that station.

The same instruments for time-determination and exchange of signals were also used. For the latter purpose the wires of the Western Union Telegraph Company were employed. The observer, E. P. Austin, was assisted at this point by two enlisted men.

Points with which connections were made.—It was intended to connect Battle Mountain with Washington and Detroit, but it was impracticable to connect with Washington, and the exchange of signals was made with Detroit only, where Mr. O. B. Wheeler, assistant United States lake-survey, conducted both observations and computations.

An explanation of the signs and symbols used in the determination of time at Detroit will be found in the report for Carlin station. The observations made at Battle Mountain were reduced in 1873 by Dr. F. Kampf, and revised in 1874. The arrangement of the report was also made by him.

Instrumental values, &c.—The instrumental values are given in the report for Carlin station. The signals were sent by sound from Battle Mountain, and recorded by eye and ear. At Detroit they were sent by sound also, but recorded on a chronograph. By means of automatic repeaters at Corinne, Cheyenne, Omaha, and Chicago, the signals were transmitted direct to the connected stations.

It has been found impossible to get a better result for longitude. The observer used for temporary monuments pieces of wood buried in the ground, which proved too unsteady to give the most accurate results. These temporary monuments were replaced later by a sandstone pier.

Computation of clock-correction for Detroit, June 1, 1871.

Ill.	Star.	$C\Delta i$	Aberr.	Bb	Cc	t'	a	$(a-t)$	v
		s.	*s.*	*s.*	*s.*	*h. m. s.*	*h. m. s.*	*m. s.*	*s.*
W.	α Serpentis	+.03	−.01	+.23	+.11	15 39 04.91	15 37 56.36	−1 08.91	+.02
	ϵ Serpentis	+.03	−.01	+.20	+.10	45 33.21	44 24.71	08.82	−.02
	ξ Ursæ Minoris	+.16	−.07	+.94	+.51	49 56.06	48 49.16	08.44	.....
	ϵ Coronæ Borealis	+.03	−.02	+.24	+.12	53 24.93	52 16.53	08.77	−.03
	β Scorpii	+.03	−.02	+.10	+.11	59 06.39	57 57.91	08.70	−.22
	δ Ophiuchi	+.03	−.01	+.12	+.10	16 08 45.31	16 07 36.71	08.84	−.06
	τ Herculis	+.04	−.02	+.27	+.15	17 02.15	15 53.74	08.85	+.02
W.	κ Ophiuchi	+.03	−.24	+.21	+.11	52 44.06	51 35.27	09.13	+.30
E.	δ Ursæ Minoris	.....	−.24	..2.18	−1.76	18 15 23.94	18 14 17.23	06.89	.....
	1 Aquilæ	−.03	−.01	+.12	−.11	29 21.54	28 12.61	08.90	−.23
	ζ Aquilæ	−.03	−.01	+.19	−.11	19 00 39.26	59 30.13	09.17	+.05
	ω Aquilæ	−.03	−.01	+.19	−.11	12 56.11	19 11 46.95	09.20	+.06
	δ Aquilæ	−.03	−.01	+.16	−.10	20 10.03	19 00 85	09.20	+.03
	γ Aquilæ	−.03	−.01	+.19	−.11	41 17.97	40 08.78	09.23	+.04
	α Aquilæ	−.03	−.01	+.19	−.11	45 39.61	44 30.50	09.15	−.05
E.	β Aquilæ	−.03	−.01	+.19	−.11	50 08.92	48 59.71	09.25	+.04

Normal equations.

$$+151.98\,a + 0.96\,\rho - 6.88\,\delta\theta + 19.62 = 0$$
$$+0.96\,a + 42.91\,\rho - 3.57 = 0$$
$$-6.88\,a + 16.00\,\delta\theta + 13.45 = 0$$

$a = -0^s.17$

$c = -0^s.10$, lamp east.

$\rho = +0^s.087$, per hour.

$\Delta t = -1^m\,08^s.91 \pm 0^s.031$, at $17^h\,38^m$.

Computation of clock-correction for Detroit, June 3, 1871.

Ill.	Star.	C Δ i	Aberr.	B b	C c	t'	a	(a−t)	v
		s.	s.	s.	s.	h. m. s.	h. m. s.	m. s.	s.
E.	ε Coronæ Borealis	−.04	−.02	+.21	−.03	15 53 30.18	15 52 16.54	−1 13.76	+.32
	β Scorpii	−.03	−.02	+.10	−.03	58 11.40	57 57.93	13.49	+.08
	δ Ophiuchi	−.03	−.01	+.13	−.03	16 08 50.28	16 07 36.73	13.61	+.15
	ξ Ophiuchi	−.03	−.01	+.10	−.03	31 18.13	30 05.02	13.44	−.10
	ζ Herculis	−.04	−.02	+.19	−.03	37 40.56	36 27.16	13.50	−.10
	η Herculis	−.04	−.02	+.20	−.03	39 43.82	38 30.30	13.63	+.01
	α Ophiuchi	−.03	−.01	+.13	−.03	17 30 12.10	17 28 58.34	13.82	+.07
E.	δ Ursæ Minoris	.....	−.24	+1.19	−.64	18 15 31.93	18 14 17.33	14.91	.....
W.	δ Ursæ Minoris	.....	−.24	+1.88	+.64	29.96	.....	14.91	.....
	1 Aquilæ	+.03	−.01	+.09	+.03	29 26.39	28 12.65	13.88	−.06
	ξ Aquilæ	+.03	−.01	+.09	+.03	19 00 44.14	59 30.17	14.11	+.06
	d Sagittarii	+.03	−.02	+.05	+.03	11 20.41	19 10 06.58	13.92	−.14
	ω Aquilæ	+.03	−.01	+.07	+.03	13 00.93	11 46.99	14.06	−.04
	δ Aquilæ	+.03	−.01	+.06	+.03	20 14.73	19 00.90	13.94	−.17
	γ Aquilæ	+.03	−.01	+.16	+.03	41 92.71	40 08.83	14.09	−.10
W.	α Aquilæ	+.03	−.01	+.21	+.03	45 44.57	44 30.55	−1 14.28	+.08

Normal equations.

$$+144.49\,a + 3.96\,\rho - 3.72\,\delta\theta - 15.88 = 0$$
$$+3.96\,a + 29.78\,\rho - 5.67 = 0$$
$$-3.72\,a + 15.00\,\delta\theta + 13.44 = 0$$

$a = +0^s.08.$
$c = +0^s.03$, lamp east.
$\rho = +0^s.201$, per hour.
$\Delta t = -1^m\,13^s.86 \pm 0^s.024$, at $17^h\,50^m$

Computation of clock-correction for Detroit, June 10, 1871.

Ill.	Star.	C Δ i	Aberr.	B b	C c	t'	a	(a−t)	v
		s.	s.	s.	s.	h. m. s.	h. m. s.	m. s.	s.
E.	α Bootis	−.03	−.02	+.13	−.03	14 11 09.32	14 09 47.84	−1 21.53	+.08
	ρ Bootis	−.04	−.02	+.15	−.03	27 39.02	26 17.59	21.49	+.10
	ε Bootis	−.03	−.02	+.14	−.03	40 44.04	39 22.60	21.50	+.09
	α^2 Libræ	−.03	−.02	+.07	−.03	45 07.50	43 46.10	21.39	−.19
E.	β Ursæ Minoris	.....	−.05	+.42	−.10	52 30.36	51 10.30	20.33	.....
W.	β Ursæ Minoris	.....	−.05	+.71	+.10	30.95	.....	20.51	.....
	β Libræ	.....	−.01	+.14	+.03	15 11 26.75	15 10 05.50	21.41	−.15
	μ^1 Bootis	+.03	−.02	+.28	+.03	20 59.72	19 38.74	21.30	−.06
	α Serpentis	+.03	−.02	+.18	+.03	39 17.67	37 56.38	21.51	.00
	ε Serpentis	+.03	−.01	+.18	+.03	45 46.17	44 24.74	21.66	+.15
	ζ Ursæ Minoris	+.16	−.07	+.88	+.13	50 08.03	48 48.83	20.30	.....
	β^1 Scorpii	.....	−.02	+.11	+.03	59 19.29	57 57.97	21.44	−.17
	ζ Ophiuchi	+.03	−.01	+.13	+.03	16 31 26.46	16 30 05.08	21.56	−.02
	κ Ophiuchi	+.03	−.01	+.17	+.03	52 56.73	51 35.35	21.60	+.09
	ε Ursæ Minoris	+.24	−.10	+1.12	+.19	17 00 44.49	59 25.78	20.16	.....
W.	α^1 Herculis	+.03	−.01	+.17	+.03	10 09.00	17 08 47.59	21.63	+.14
W.	η Serpentis	+.03	−.01	+.12	+.03	18 16 01.00	18 14 39.64	21.53	−.04
W.	51 Cephei, L. C	.....	+.29	−3.06	−.53	40 18.12	6 38 49.29	25.53	.....
E.	51 Cephei, L. C	.....	+.29	−.65	+.53	14.64	.....	.52	.....
	ζ Aquilæ	−.03	−.01	+.06	−.03	19 00 51.88	59 30.32	21.55	+.04
	d Sagittarii	−.03	−.02	+.05	−.03	11 28.38	19 10 06.75	21.60	−.05
	ω Aquilæ	−.03	−.01	+.10	−.03	13 08.75	11 47.14	21.64	+.12
	δ Aquilæ	−.03	−.01	+.10	−.03	20 22.64	19 01.05	21.62	−.03
E.	ε Aquilæ	−.03	−.01	+.10	−.03	31 19.97	29 58.46	−1 21.54	−.06

Normal equations.

$$+296.13\,a - 38.83\,\rho + 17.03\,\delta\theta + 84.99 = 0$$
$$-38.83\,a + 69.42\,\rho - 12.35 = 0$$
$$+17.03\,a + 22.00\,\delta\theta + 11.92 = 0$$

$a = -0^s.03$
$c = -0^s.03$, lamp east.
$\rho = +0.009$, per hour.
$\Delta t = -1^m.21^s.34 \pm 0^s.017$, at $16^h\,42^m$

Battle Mountain, Nev., June 1, 1871.

Name of star.	Clamp.	T	*b* B	*a* A	*c* C	T′	AR.	Δ T
		h. m. s.	*s.*	*s.*	*s.*	*h. m. s.*	*h. m. s.*	*m. s.*
α Virginis	W.	13 17 5.98	+ 0.02	+ 3.23	+ 0 42	13 17 9.65	13 18 25.01	+ 1 15.36
ζ Virginis		26 49.52	+ 0.08	+ 2.66	+ 0.41	26 52.67	28 8.32	15.65
η Ursæ Majoris		41 13.48	+ 0.26	− 1.02	+ 0.64	41 13.36	42 28.88	15.52
η Bootis		47 16.24	+ 0.18	+ 1.60	+ 0.43	47 18.45	48 33.74	15.29
50 Cap., L. C		50 59.16	− 0.23	+12.11	− 1.31	51 9.73	52 25.27	15.54
τ Herculis	E.	16 14 39.59	− 0.36	− 0.61	− 0.60	16 14 38.02	16 15 53.75	15.73
α Scorpii		20 12.34	− 0.11	+ 4.17	− 0.46	20 15.94	21 31.80	15.86
15 Draconis		27 10.04	− 0.54	− 5.44	− 1.15	27 2.91	28 18.51	15.60
α Camelop., L. C		39 44.96	+ 0.14	+ 9.65	+ 1.01	39 55.76	41 11.40	15.64
ε Ursæ Minoris		58 35.38	− 1.21	−20.12	− 3.04	58 11.01	59 25.98	+ 1 14.97
Mean for 15h 0m local sidereal time								+ 1 15.52

Four different computations to find the error of chronometer were made. The error of collimation adopted from two computations = − 0s.41. The method of least squares gave an unsatisfactory result: the azimuth of the instrument was therefore computed from polar and south stars = + 4s.09. *β* Draconis is excluded in the above determination of time, as it gives a result differing too much from those of the other stars.

Battle Mountain, Nev., June 3, 1871.

Name of star.	Clamp.	T	*b* B	*a* A	*c* C	T′	AR.	Δ T
		h. m. s.	*s.*	*s.*	*s.*	*h. m. s.*	*h. m. s.*	*m. s.*
ζ Virginis	W.	13 26 52.96	− 0.16	+ 0.33	+ 0.32	13 26 53.45	13 28 8.31	+1 14.86
η Ursæ Majoris		41 13.50	− 0.11	− 0.13	+ 0.50	41 13.76	42 28.85	15.09
η Bootis		47 18.44	− 0.12	+ 0.20	+ 0.34	47 18.86	48 33.74	14.88
50 Cassiop., L. C		51 9.85	+ 0.20	+ 1.50	− 1.02	51 10.53	52 25.39	14.86
α Draconis		59 41.45	− 0.35	− 0.49	+ 0.86	59 41.47	14 0 46.21	+1 14.74
Mean for 13h 45m local sidereal time								+1 14.86

Normal equations.

$$0 = -0.23 + 5.00\,\delta t + 2.78\,a \qquad \delta t = -0^s.115$$
$$0 = -2.86 + 2.78\,\delta t + 10.33\,a \qquad a = +0^s.308$$

By preliminary reduction the error of collimation is found = − 0s.32; adopted error of azimuth = + 0s.20. The azimuth of the instrument found by the method of least squares = + 0s.508.

Battle Mountain, Nev., June 3, 1871.

Name of star.	Clamp.	T	*b* B	*a* A	*c* C	T′	AR.	Δ T
		h. m. s.	*s.*	*s.*	*s.*	*h. m. s.*	*h. m. s.*	*m. s.*
δ Corvi	E.	12 22 51.52	−0.02	+5.84	−0.33	12 42 57.01	12 23 12.00	+1 12.99
κ Draconis		26 55.48	−0.08	−9.99	−0.96	26 44.45	27 59.50	15.05
γ Virginis		33 49.00	−0.04	+4.43	−0.32	33 53.07	35 8.07	15.00
35 Virginis		40 59.21	−0.06	+4.02	−0.32	41 2.85	41 18.10	15.25
12 Canum Venat.		48 45.52	−0.14	+0.27	−0.41	48 45.24	50 0.39	15.15
Virginis		54 28.28	−0.12	+3.35	−0.33	54 31.18	55 46.32	15.14
θ Virginis		13 1 57.84	−0.10	+4.83	−0.32	13 2 2.25	13 3 17.30	+1 15.05
Mean for 12h 40m local sidereal time								+1 15.00

Normal equations.

$$0 = +0.05 + 7.00\,\delta t + 1.90\,a \qquad \delta t = -0^s.01$$
$$0 = -0.02 + 1.90\,\delta t + 4.55\,a \qquad a = +0^s.009$$

The error of collimation is found by preliminary reduction..... = − 0s.32
The azimuth was determined by *δ* Corvi and *κ* Draconis..... = + 6s.70
And by mean of the least squares the azimuth is given ..... = + 6s.709

Battle Mountain, Nev., June 10, 1871.

Name of star.	Clamp.	T	*b* B	*a* A	*c* C	T′	AR.	Δ T
		h. m. s.	*s.*	*s.*	*s.*	*h. m. s.*	*h. m. s.*	*m. s.*
ξ Ursæ Minoris ..	W.	15 47 41.85	−2.25	+0.40	+0.06	15 47 40.06	15 48 48.84	+1 8.78
δ Scorpii	.....	51 35.88	−0.24	−0.13	+0.01	51 35.52	52 44.21	8.69
β^1 Scorpii	.....	56 49.56	−0.29	−0.12	+0.01	56 49.16	57 57.97	8.81
Groom. 2320.....	.....	16 4 54.42	−1.43	+0.17	+0.03	16 4 53.19	16 6 2.00	8.41
τ Herculis	.....	14 45.42	−0.83	+0.02	+0.02	14 44.63	15 53.76	9.13
α Scorpii	.....	20 23.40	−0.24	−0.13	+0.01	20 23.04	21 31.88	8.84
Mean for 16h 0m local sidereal time								+1 8.84

Normal equations.

$0 = +0.59 + 6.00\,\delta t - 1.47\,a - 12.29\,c \qquad t = -0^s.16$

$0 = +1.73 - 1.47\,\delta t + 13.47\,a + 13.71\,c \qquad a = -0^s.133$

$0 = +0.36 - 12.28\,\delta t + 13.71\,a + 36.75\,c \qquad c = -0^s.012$

From the preceding observations, the following table containing corrections of chronometer and adopted rates for Negus No. 1344 is derived.

1871.	*h.*	*m.*	*s.*	*s.*
June 1,	15.0 local sidereal time: cor. of chronometer,	+ 1	15.52; adopted rate,	+ 0.011
June 3,	13.2 local sidereal time: cor. of chronometer,	+ 1	14.99; adopted rate,	+ 0.023
June 10,	14.8 local sidereal time: cor. of chronometer,	+ 1	8.84; adopted rate,	+ 0.035

Before and after exchange, comparisons of Negus 1344 and Hutton 288 (mean solar chronometer) were made, as follows:

1871.	*h. m. s.*	*h. m. s.*	*h. m. s.*
June 1. Negus 1374.....	13 56 30.0	13 59 34.0	
Hutton 288.....	8 55 57.5	8 58 51.0	
After exchange:			
Negus 1344.....	15 57 56.0	16 00 59.0	16 4 6.0
Hutton 288.....	10 56 53.5	10 59 56.0	11 3 2.5
June 3. Negus 1344.....	14 5 2.0	14 8 5.0	
Hutton 288.....	8 56 25.0	8 59 27.5	
After exchange:			
Negus 1344.....	15 0 40.5	15 3 44.0	15 6 49.0
Hutton 288.....	9 51 54.0	9 54 57.0	9 58 1.5
June 10. Negus 1344.....	14 14 13.0	14 17 17.0	
Hutton 288.....	8 37 57.0	8 41 0.5	
After exchange:			
Negus 1344.....	15 38 24.0	15 41 26.0	
Hutton 288.....	10 1 54.0	10 4 55.5	

From these comparisons the following table for mean-time chronometer Hutton 288 is derived.

Hutton 288.

	Hutton time.	Slow of sidereal time.	Losing per hour.	Log.
	h.	*h. m. s.*	*s.*	
June 1, 1871.....	8.95535	5 1 58.28	9.898	0.9955363
	10.99925	2 18.51		
June 3, 1871.....	8.96562	9 52.20	10.249	1.0106754
	9.91597	10 1.94		
June 10, 1871.....	8.65799	37 25.11	9.949	0.9977580
	10.06021	37 39.06		

Exchange of signals between Detroit, Mich., and Battle Mountain, Nev.

JUNE 1, 1871.—*Signals sent from Detroit.*

Detroit clock.			Battle Mountain chronometer.			Detroit clock.			Battle Mountain chronometer.			Detroit clock.			Battle Mountain chronometer.		
h.	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*		*h.*	*m.*	*s.*	*h.*	*m.*	*s.*
17	22	40.25	10	3	49.80			.....	10	5	.....		17	26	20.05	10	7	29.00
		50.06			50.60	17	24	40.10			49.30				30.20			39.00
	23	0.35		4	9.80			50.20			59.10				40.20			49.00
							25	0.24		6	9.40				50.15			59.00
	24	0.21		5	9.80									27	0.21		8	9.00
		10.03			19.20		26	0.25		7	9.30							
		20.05			29.20			10.19			19.00	Mean,	17	25	3.92	10	6	13.03

SECOND SERIES.

Detroit clock.			Battle Mountain chronometer.			Detroit clock.			Battle Mountain chronometer.			Detroit clock.			Battle Mountain chronometer.		
h.	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*		*h.*	*m.*	*s.*	*h.*	*m.*	*s.*
17	52	40.29	10	33	44.80	17	54	50.10	10	35	54.40		17	57	0.05	10	38	4.00
		50.21			54.70		55	0.08		36	4.30				10.05			14.00
	53	0.21		34	4.60			10.18			14.30				20.10			23.90
		10.20			14.50			20.10			24.00				30.20			33.90
		20.15			24.50			30.20			34.10				40.10			44.00
		30.20			34.50			40.20			44.20							
		40.11			44.50							Mean,	17	55	10.14	10	36	14.26
							56	40.05		37	43.90							
	54	40.08		35	44.30			50.14			54.00							

Signals sent from Battle Mountain.

Detroit clock.			Battle Mountain chronometer.			Detroit clock.			Battle Mountain chronometer.			Detroit clock.			Battle Mountain chronometer.		
h.	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*		*h.*	*m.*	*s.*	*h.*	*m.*	*s.*
17	40	24.31	10	22	10.00	17	44	54.92	10	26	40.00		17	46	15.10	10	28	0.00
		29.50			15.00			59.95			45.00				20.05			5.00
		34.22			20.00		45	4.90			50.00				25.12			10.00
		39.31			25.00			9.92			55.00				30.25			15.00
		44.28			30.00			14.91		27	0.00				35.20			20.00
		49.45			35.00			19.90			5.00				40.50			25.00
		54.60			40.00			24.98			10.00				45.35			30.00
								30.10			15.00				50.30			35.00
	44	14.88		26	0.00			35.15			20.00				55.31			40.00
		19.69			5.00			40.40			25.00			47	0.20			45.00
		24.80			10.00			45.10			30.00				5.19			50.00
		29.90			15.00			50.27			25.00				10.30			55.00
		34.88			20.00			55.06			40.00				15.20		29	0.00
		39.92			25.00		46	0.20			45.00							
		45.00			30.00			5.18			50.00	Mean,	17	44	56.44	10	26	41.48
		49.75			35.00			10.06			55.00							

JUNE 3, 1871.—*Signals sent from Detroit.*

Detroit clock.			Battle Mountain chronometer.			Detroit clock.			Battle Mountain chronometer.			Detroit clock.			Battle Mountain chronometer.		
h.	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*		*h.*	*m.*	*s.*	*h.*	*m.*	*s.*
16	41	.....	9	14	.....	16	43	10.12	9	16	28.80		16	45	20.05	9	18	38.40
		10.25			29.10			20.08			38.60				30.25			48.50
		20.00			39.00			30.10			48.60				40.12			58.50
		30.15			49.10			40.20			58.70				50.12		19	8.30
		40.25			59.10			50.29		17	8.60			46	0.40			18.50
		50.37		15	9.20		44	0.30			18.80							
	42	0.25			19.00							Mean,	16	43	37.70	9	16	56.24
							45	0.28		18	18.60							
	43	0.38		16	19.00			10.08			28.40							

SECOND SERIES.

Detroit clock.			Battle Mountain chronometer.			Detroit clock.			Battle Mountain chronometer.			Detroit clock.			Battle Mountain chronometer.		
h.	m.	s.	h.	m.	s.	h.	m.	s.	h.	m.	s.		h.	m.	s.	h.	m.	s.
17	0	0.25	9	31	16.50	17	2	10.20	9	33	25.80		17	4	20.20	9	35	35.40
		10.05			26.10			20.18			35.80				.....			.....
		20.13			36.20			30.15			45.80			40.18			55.50
		30.21			46.30			40.21			55.80			50.25		36	5.40
		40.11			56.00			50.13		34	6.00			5	0.20			15.20
		50.23		32	6.00		3	0.18			16.00							
	1	0.41			16.00							Mean,	17	2	24.19	9	33	39.83
							4	0.10		35	15.40							
	2	0.30		38	15.90			10.20			25.50							

Signals sent from Battle Mountain.

Detroit clock.			Battle Mountain chronometer.			Detroit clock.			Battle Mountain chronometer.			Detroit clock.			Battle Mountain chronometer.		
h.	m.	s.	h.	m.	s.	h.	m.	s.	h.	m.	s.		h.	m.	s.	h.	m.	s.
16	49	43.23	9	23	0.00	16	51	28.72	9	24	45.00		16	53	13.93	9	26	30.00
		48.30			5.00			33.45			50.00				19.05			35.00
		53.12			10.00			38.60			55.00				23.88			40.00
		58.20			15.00			43.70		25	0.00				28.80			45.00
	50	3.30			20.00			48.70			5.00				33.90			50.00
		8.83			25.00			53.59			10.00				38.85			55.00
		13.50			30.00			58.59			15.00				43.82		27	0.00
		18.61			35.00		52	3.85			20.00				48.90			5.00
		23.68			40.00			8.83			25.00				53.80			10.00
		28.68			45.00			13.81			30.00				59.10			15.00
		33.45			50.00			18.89			35.00			54	4.10			20.00
		38.60			55.00			23.78			40.00				9.34			25.00
		43.42		24	0.00			28.71			45.00				14.10			30.00
		48.41			5.00			33.74			50.00				19.20			35.00
		53.45			10.00			38.59			55.00				24.36			40.00
		58.55			15.00			43.60		26	0.00				29.20			45.00
	51	3.50			20.00			48.68			5.00				34.08			50.00
		8.82			25.00			53.70			10.00				39.15			55.00
		13.60			30.00			58.75			15.00				44.00		28	0.00
		18.70			35.00		53	3.71			20.00							
		23.70			40.00			8.95			25.00	Mean,	16	52	13.75	9	25	30.00

JUNE 10, 1871.—*Signals sent from Detroit.*

Detroit clock.			Battle Mountain chronometer.			Detroit clock.			Battle Mountain chronometer.			Detroit clock.			Battle Mountain chronometer.		
h.	m.	s.	h.	m.	s.	h.	m.	s.	h.	m.	s.		h.	m.	s.	h.	m.	s.
17	12	.....	9	17	.....	17	14	10.00	9	19	44.80		17	16	20.10	9	21	54.60
		10.10			45.10			20.15			54.90				30.10		22	4.50
		20.25			55.40			30.10		20	4.90				40.10			14.40
		30.20		18	5.40			40.10			14.90				50.15			24.20
		40.45			15.50			50.20			24.80			17	0.55			34.10
		50.20			25.10		15	0.10			34.60							
	13	0.20			35.10							Mean,	17	14	37.69	9	20	12.32
							16	0.43		21	34.60							
	14	0.25		19	35.10			10.10			44.40							

SECOND SERIES.

Detroit clock.			Battle Mountain chronometer.			Detroit clock.			Battle Mountain chronometer.			Detroit clock.			Battle Mountain chronometer.		
h.	m.	s.	h.	m.	s.	h.	m.	s.	h.	m.	s.		h.	m.	s.	h.	m.	s.
17	26	30.24	9	32	3.00	17	28	40.21	9	34	12.60		17	30	50.15	9	36	22.00
		40.00			12.70			50.21			22.50			31	0.00			32.00
		50.20			22.70			59.84			32.20				10.26			42.10
	27	0.20			32.70		29	10.12			42.40				20.10			52.00
		10.10			42.60			20.15			52.40				30.30		37	2.10
		20.12			52.50			30.21		35	2.40							
		30.10		33	2.60							Mean,	17	29	0.15	9	34	32.40
							30	30.21		36	2.20							
	28	30.27		34	2.60			40.18			12.20							

Signals sent from Battle Mountain.

Detroit clock.			Battle Mountain chronometer.			Detroit clock.			Battle Mountain chronometer.			Detroit clock.			Battle Mountain chronometer.		
h.	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*		*h.*	*m.*	*s.*	*h.*	*m.*	*s.*
17	19	26.69	9	25	0.00	17	21	6.93	9	26	40.00		17	22	47.29	9	28	20.00
		31.75			5.00			12.08			45.00				52.38			25.00
		36.60			10.00			17.20			50.00				57.30			30.00
		41.80			15.00			21.86			55.00			23	2.46			35.00
		46.90			20.00			27.08		27	0.00				7.42			40.00
		51.84			25.00			32.01			5.00				12.49			45.00
		56.88			30.00			36.82			10.00				17.45			50.00
	20	1.92			35.00			41.90			15.00				22.50			55.00
		7.15			40.00			47.18			20.00				27.55		29	0.00
		12.10			45.00			51.92			25.00				32.41			5.00
		17.03			50.00			57.25			30.00				37.48			10.00
		22.00			55.00		22	2.15			35.00				42.40			15.00
		26.90		26	0.00			7.24			40.00				47.62			20.00
		32.00			5.00			12.45			45.00				52.55			25.00
		37.00			10.00			17.25			50.00				57.50			30.00
		41.96			15.00			22.50			55.00			24	2.72			35.00
		46.95			20.00			27.35		28	0.00							
		51.95			25.00			32.35			5.00	Mean,	17	21	44.66	9	27	17.50
		56.98			30.00			37.32			10.00							
	21	2.00			35.00			42.30			15.00							

Deduction of the results for longitude.

Date.	Signals sent from—	Detroit clock.	Clock correction.	Local sidereal time of the mean of the signals.	Battle Mountain chronometer.	Correction of chronometer.	Local sidereal time of the mean of the signals.	Differences of longitude.	Mean.	Double-wave time.	Final differences of longitude.
		h. m. s.	*m. s.*	*h. m. s.*	*h. m. s.*	*h. m. s.*	*h. m. s.*	*h. m. s.*	*s.*	*s.*	*h. m. s.*
June 1, 1871	Detroit to Battle Mountain	17 25 3.92	−1 8.91	17 23 55.01	10 6 13.03	+5 2 9.65	15 8 22.68	2 15 32.33	.....	.....	.....
June 1, 1871	Detroit to Battle Mountain	17 55 10.14	1 8.94	17 54 1.20	10 36 14.26	2 14.60	15 38 28.86	32.34	32.34	.....	.....
June 1, 1871	Battle Mountain to Detroit	17 44 56.44	1 8.92	17 43 47.52	16 26 41.48	2 13.02	15 28 54.50	33.02	33.02	0.68	2 15 32.68
June 3, 1871	Detroit to Battle Mountain	16 43 37.70	−1 13.64	16 42 24.06	9 16 56.24	+5 9 55.45	14 26 51.69	32.37	.....	.....	.....
June 3, 1871	Detroit to Battle Mountain	17 2 24.19	1 13.69	17 1 10.50	9 33 39.83	9 58.30	14 43 38.13	32.37	32.37	.....	.....
June 3, 1871	Battle Mountain to Detroit	16 52 13.75	1 13.67	16 51 0.08	9 25 30.00	9 56.91	14 35 26.91	33.17	33.17	0.80	32.77
June 10, 1871[1]	Detroit to Battle Mountain	17 14 37.69	−1 21.34	17 13 16.35	9 20 12.32	+5 37 31.87	14 57 44.19	32.16	.....	.....	.....
June 10, 1871	Detroit to Battle Mountain	17 29 0.15	1 21.35	17 27 38.80	9 34 32.40	37 34.24	15 12 6.64	32.16	32.16	.....	.....
June 10, 1871	Battle Mountain to Detroit	17 21 44.66	1 21.34	17 20 23.32	9 27 17.50	37 33.04	15 4 50.54	32.78	32.78	0.62	32.47

Battle Mountain west of Detroit $2^h\ 15^m\ 32^s.64 \pm 0^s.06$.

Mean places of stars for 1871.0 *used for determination of latitude of Battle Mountain, Nev.*

No. of pair.	No. in B. A. C.	Declination.	No. of pair.	No. in B. A. C.	Declination.	No. of pair.	No. in B. A. C.	Declination.
		° ′ ″			° ′ ″			° ′ ″
1	4568	55 20 5.00	7	4825	37 11 39.22		5385	36 49 12.83
	4594	26 21 2.56		4841	44 11 57.58	13	5400	44 9 52.74
2	4605	55 4 38.28	8	4863	37 18 26.30			
						14	5432	34 11 14.06
	4640	29 17 1.25		4952	47 47 15.90		5463	46 37 18.00
3	4684	51 35 32.39	9	5000	33 34 10.00	15	5479	34 6 14.86
	4694	31 28 3.52		5072	33 23 49.53		5541	30 46 15.78
4	4701	50 4 5.00	10	5113	48 9 26.29	16	5549	50 24 52.55
	4723	29 42 34.42		5157	43 35 44.60		5596	49 10 53.84
5	4752	51 54 18.25	11	5178	37 3 21.00	17	5604	31 50 17.80
	4804	50 25 22.70		5252	21 22 3.96		5752	56 52 42.77
6	4808	30 56 20.26	12	5307	59 17 3.64	18	5798	24 23 49.00

Observations for latitude.—Station, Battle Mountain, Nev.

Date.	No. of star.	Micrometer-readings.	Level. N.	Level. S.	Remarks.	Date.	No. of star.	Micrometer-readings.	Level. N.	Level. S.	Remarks.
1871.		t. d.				1871.		t. d.			
June 6	5432	1 41.5	18.2	15.5		June 8	5252	7 91.0	15.0	10.0	
	5463	22 13.9	18.5	15.2			5307	36 67.0	10.0	15.0	
	5479	−2 34.4	18.2	15.8							
							5385	8 97.8	13.0	12.5	
	5541	12 62.2	17.5	16.8			5400	26 90.5	14.8	11.0	Must be 21'.
	5549	16 49.0	22.0	12.0							
							5432	13 76.8	15.8	10.0	
June 7	5252	7 48.2	17.0	15.0			5463	34 43.5	12.8	13.0	
	5307	35 8.2	18.0	13.8			5479	10 1.6	15.8	10.0	
	5385	11 72.2	21.8	10.2			5541	18 16.2	9.5	16.8	
	5400	24 59.5	12.8	19.0			5549	21 98.9	21.2	5.0	
	5432	13 81.0	15.6	15.0			5596	25 79.9	12.0	14.0	
	5463	34 47.8	20.0	12.8			5604	14 51.0	17.5	8.8	
	5479	10 19.2	16.3	16.3							
							5752	23 64.8	17.8	9.2	
	5541	18 53.0	20.3	13.0			5798	23 83.8	17.0	10.2	
	5549	22 35.3	18.0	15.0		June 9					
							4568	9 86.2	12.0	11.0	
June 8	4568	11 10.0	12.0	10.5			4594	28 12.0	8.0	15.8	
	4594	29 47.0	12.0	10.5							
	4605	22 55.8	10.7	12.0			4640	10 87.9	13.5	10.3	
							4684	28 79.0	4.0	20.8	
	4640	11 88.8	10.2	12.2							
	4684	29 50.3	13.0	10.2			4694	26 40.2	6.2	18.8	
							4701	14 80.0	17.0	8.0	
	4694	26 51.0	15.5	8.0							
	4701	14 83.6	8.0	16.0			4723	25 68.9	11.2	13.5	Must be 23'.
							4752	5 93.8	11.2	13.2	
	4723	23 28.0	12.6	11.8							
	4752	5 48.9	14.0	10.3	Is No. 4742.		4804	12 78.2	12.0	13.0	
							4808	16 67.7	13.0	12.2	
	4825	23 27.9	14.8	10.0							
	4841	17 78.8	14.0	10.5			4825	22 94.2	14.0	11.8	
	4863	28 28.0	14.0	11.0			4841	17 56.7	12.8	13.2	
							4863	27 94.5	16.0	10.5	
	5072	24 9.1	11.8	11.8							
	5113	11 63.6	12.8	11.8			4952	20 42.5	19.2	7.8	
							5000	24 28.5	13.0	15.0	
	5157	32 29.5	15.0	9.5							
	5178	4 65.3	10.0	14.8			5072	23 56.7	14.0	14.0	
							5113	10 87.0	20.8	7.2	

Computations for latitude of Battle Mountain, Nev.

Date.	No. of pair.	Half-sum of declination.	Corrections.			Latitude.
			Micr. and refr.	Level.	Merd.	
		° ′ ″	′ ″	″		° ′ ″
June 6, 1871		40 24 17.66	+13 58.11	+ 4.05		40 38 19.82
		21 47.85	+16 30.13	+ 3.85		21.83
		35 35.02	+ 2 36.42	+ 7.26		18.70
June 7, 1871		40 19 36.46	+18 36.24	+ 4.19		16.89
		29 34.96	+ 8 40.61	+ 3.64		19.21
		24 17.95	+13 56.25	+ 5.26		19.46
		21 48.09	+16 22.16	+ 4.86		15.11
		35 35.30	+ 2 34.57	+ 6.95		16.82
June 8, 1871		40 50 41.76	−12 22.92	+ 2.02		40 38 20.86
		42 56.26	− 4 39.54	+ 0.14		16.86
		26 24.30	+11 52.38	+ 0.54		17.22
		46 11.65	− 7 52.12	+ 0.34		19.19
		50 17.23	−11 59.50	+ 3.04		20.77
		41 54.87	− 3 42.07	+ 5.60		18.40
		45 18.28	− 7 4.31	+ 4.32		18.29
		46 42.34	− 8 23.70	+ 0.67		19.31
		19 36.73	+18 37.91	+ 0.47		15.11
		19 36.72	+18 42.71	0.00		19.43
		29 35.22	+ 8 42.78	+ 2.90		20.90
		24 18.20	+13 55.82	+ 3.78		17.80
		21 48.38	+16 27.55	+ 3.78		19.71
		35 35.57	+ 2 34.77	+ 6.01		16.35
		30 36.80	+ 7 26.54	+ 4.52		17.86
		38 15.72	− 0 7.68	+10.39		18.43
June 9, 1871		40 50 41.91	−12 18.29	− 4.59		18.93
		26 24.51	+12 4.34	− 9.18		19.67
		46 11.84	− 7 49.20	− 2.43		20.21
		50 17.41	−11 57.88	− 2.90		16.63
		40 58.28	− 2 37.51	− 0.14		20.63
		41 55.08	− 3 37.37	+ 1.21		18.92
		45 18.49	− 6 59.70	+ 3.44		22.23
		40 48.50	− 2 36.10	+ 6.34		18.74
		46 42.59	− 8 33.49	+ 9.18		18.28

Mean latitude of Battle Mountain, Nev., 40° 38′ 18″.74 ±0″.21.

Resulting astronomical co-ordinates.

Adopting the longitude of Detroit as given in the Report of the Chief of Engineers for 1871, to be—
0h 24m 0.14s west of Washington, or
83° 3′ 3″.90 west of Greenwich—
The resulting astronomical co-ordinates of Battle Mountain, Nev., will be—
Longitude: 116° 56′ 13″.50 west of Greenwich.
39° 53′ 11″.70 west of Washington.
Latitude: N. 40° 38′ 18″.74 ±0″.21.

AUSTIN, NEVADA.

Longitude 117° 03′ 41″.70; latitude 39° 29′ 21″.92.

The astronomical station is situated near Austin, Nev., in the cañon through which the road to Belmont passes. A short distance above the Manhattan Mill, to the east of the station, the land rises rapidly to Mount Prometheus; to the north, there is a slope downward to the valley of the Reese River. The mountains to the south and west rise to a height of several hundred feet above the station. The weather seems to have been quite fair when the station was occupied; at least, at night. During the day the clouds accumulated about 3 p. m., clearing again at 11 p. m. No detailed meteorological observations were made by the observer. The observations were taken in the same tent used at Carlin and Battle Mountain; the instrument was placed on three pieces of board buried three feet in the ground. The observer, E. P. Austin, was assisted by two soldiers.

The wires of the Western Union Telegraph Company were used for exchange of signals. For time and latitude observations the same instruments were used as at Carlin and Battle Mountain, a description of which is given in the proper place in the report on Carlin.

Connection was made with Washington and Detroit; Washington could be reached only once. The result derived from the exchanges between Austin, and Detroit and Washington for the longitude of Detroit is again larger than that given in the Report of the Chief of Engineers for 1871. This discrepancy of the results, being all independent of each other, will be investigated at another time.

The observations for time were taken on the 16th, 26th, and 29th of June; those for latitude on June 15, 17, 21, and 23. The corresponding determinations for time at Detroit were taken by Mr. O. B. Wheeler, assistant United States lake-survey, and at Washington by Prof. John R. Eastman, United States Naval Observatory. The reductions of the observations, made at the connected places, were made in the respective offices; those for Austin station by Dr. F. Kampf, who also prepared the report.

The explanation of signs in the report for the Detroit observations will be found in the report for Carlin; the same report contains the observations and computations for time relating to Washington.

For the reductions of observations made at Austin, the same instrumental values as given in the report on Carlin station were used. The signals were sent through by means of automatic repeaters; the number of them and also the places where they are situated are given in the Carlin report.

Computation of clock-correction for Detroit, June 16, 1871.

Ill.	Star.	C △ i	Aberr.	B b	C c	t'	a	(a—t)	t
		s.	s.	s.	s.	h. m. s.	h. m. s.	m. s	s
W.	β Bootis	+ .04	− .02	+ .29	+ .08	14 58 32.36	14 57 06.78	−1 25.97	−.10
	48 Cephei, L. C.	.....	+ .06	− .47	− .29	15 05 25.12	3 03 58.79	25.63	.....
	β Libræ	+ .03	− .01	+ .14	+ .07	11 30.94	15 10 05.49	25.68	−.15
	α Coronæ Borealis	+ .03	− .02	+ .23	+ .07	30 40.68	29 15.14	25.85	−.06
	α Serpentis	+ .03	− .01	+ .19	+ .07	39 22.07	37 56.38	25.97	−.12
	ε Serpentis	+ .03	− .01	+ .19	+ .06	45 50.31	44 24.75	25.83	−.08
	ζ Ursæ Minoris	+ .16	− .07	+ .97	+ .31	50 12.81	48 48.52	25.66	−.16
	ε Coronæ Borealis	+ .03	− .02	+ .28	+ .07	53 42.05	52 16.54	25.87	−.06
W.	δ Ophiuchi	+ .03	− .01	+ .18	+ .06	16 09 02.44	16 07 36.79	25.91	−.09
E.	ζ Ophiuchi	− .03	− .01	+ .12	− .07	31 30.68	30 05.11	25.58	−.32
	η Herculis	− .04	− .02	+ .24	− .08	39 56.30	38 30.35	26.05	−.11
	κ Ophiuchi	− .03	− .01	+ .17	− .07	53 01.20	51 35.39	25.87	−.05
	ε Ursæ Minoris	.....	− .10	+1.16	− .47	17 00 50.24	59 25.52	25.31	.....
E.	α¹ Herculis	− .03	− .02	+ .18	− .07	10 13.51	17 08 47.64	25.93	−.09
E.	κ Aquilæ	− .03	− .01	+ 06	− .07	19 31 24.57	19 29 58.59	25.93	−.01
	γ Aquilæ	− .03	− .01	+ .08	− .07	41 35.08	40 09.12	25.93	−.05
	α Aquilæ	− .03	− .01	+ .08	− .07	45 56.92	44 30.85	26.04	−.07
	β Aquilæ	− .03	− .01	+ .07	− .07	50 26.10	49 00.06	26.00	−.07
E.	λ Ursæ Minoris	.....	− .74	+3.88	−3.39	19 55 44.83	54 13.55	31.03	.....
W.	λ Ursæ Minoris	.....	+ .74	+3.88	.....	29.67	.....	.....	.....
	α² Capricorni	+ .03	− .01	+ .06	+ .07	20 12 21.07	20 10 55.20	26.02	−.05
W.	ε Delphini	+ .03	− .01	+ .09	+ .07	28 30.22	27 04.33	26.07	−.06

Normal equations.

$$+ 49.63\,a + 9.61\,\rho + 1.74\,\delta\theta + 3.60 = 0$$
$$+ 1480.91\,a' + 90.89\,\rho - 34.62\,\delta\theta - 228.03 = 0$$
$$+ 9.61\,a + 90.89\,a' + 77.44\,\rho - 16.81 = 0$$
$$+ 1.74\,a - 34.62\,a' + 21.00\,\delta\theta + 23.13 = 0$$

$a = - 0^s.01$
$a' = + 0^s.14$
$c = - 0^s.06$ lamp east.
$\rho = + 0^s.051$, per hour.

$\Delta t = - 1^m\ 25^s.93 \pm 0^s.019$ at $17^h\ 19^m$

Computation of clock-correction for Detroit, June 26, 1871.

Ill.	Star.	C Δ *i*	Aberr.	B *b*	C *c*	*t'*	*α*	(*α*−*t*)	*v*
		s.	*s.*	*s.*	*s.*	*h.* *m.* *s.*	*h.* *m.* *s.*	*m.* *s*	*s.*
E.	β Bootis	−.08	−.02	+ .15	− .10	14 58 35.55	14 57 06.66	−1 28.84	+.16
	48 Cephei, L. C	+.14	+.06	− .27	+ .35	15 05 28.01	15 03 59.68	28.61	.....
	μ^1 Bootis	−.08	−.02	+ .18	− .10	21 07.49	19 38.63	28.84	+.17
	α Coronæ Borealis	−.07	−.02	+ .17	− .09	30 43.75	29 15.09	28.65	+.01
	α Scorpii	−.06	−.01	+ .13	− .08	39 24.93	37 56.37	28.54	+.06
	ε Serpentis	−.06	−.01	+ .14	− .08	45 53.16	44 24.74	28.41	−.19
	ε Coronæ Borealis	−.07	−.02	+ .20	− .09	53 45.14	52 16.50	28.66	+.04
	δ Ophiuchi	−.06	−.01	+ .14	− .08	16 09 05.23	16 07 36.81	28.41	−.16
	ζ Ophiuchi	−.06	−.01	+ .13	− .08	31 33.49	30 05.14	28.33	−.21
E.	κ Ophiuchi	−.06	−.01	+ .18	− .08	53 03.93	51 35.42	28.54	.00
W.	δ Ophiuchi	+.06	−.01	+ .15	+ .08	17 30 26.85	17 28 58.56	28.57	+.05
W.	ζ Aquilæ	+.06	−.01	+ .20	+ .08	19 00 58.79	18 59 30.57	28.55	+.11
	ω Aquilæ	+.06	−.01	+ .16	+ .08	13 15.69	19 11 47.40	28.58	+.14
	δ Aquilæ	+.06	−.01	+ .13	+ .08	20 29.48	19 01.35	28.39	−.02
	κ Aquilæ	+.06	−.01	+ .10	+ .08	31 26.91	29 58.78	28.36	−.02
W.	λ Ursæ Minoris	.....	−.74	+4.78	+4.12	55 40.46	54 16.37	32.25	.00
E.	ε Delphini	−.06	−.01	+ .11	− .08	20 28 32.83	20 27 04.55	28.24	−.13
	α Cygni	−.08	−.02	+ .18	− .11	38 32.63	37 03.96	28.64	+.22
	μ Aquarii	−.06	−.01	+ .08	− .08	47 11.52	45 43.19	28.26	−.06
	32 Vulpeculæ	−.07	−.02	+ .12	− .09	50 33.70	49 05.35	28.29	−.06
	61^1 Cygni	−.08	−.02	+ .16	− .10	21 02 37.45	21 01 08.83	28.58	+.10
E.	ζ Cygni	−.07	−.02	+ .13	− .09	08 56.69	07 28.32	28.32	−.04

Normal equations.

$$-1502.25\,\alpha + 83.30\,\rho - 25.67\,\delta\theta - 157.33 = 0$$
$$-\ 83.30\,\alpha + 111.16\,\rho \qquad\quad - \ 2.30 = 0$$
$$-\ 25.67\,\alpha \qquad + 22.00\,\delta\theta - 14.86 = 0$$

$\alpha = -0^s.10$

$c = -0^s.08$, lamp east.

$\rho = -0^s.053$, per hour.

$\Delta t = -1^m\ 28^s.54 \pm 0^s.01^9$, at $18^h\ 04^m$

Computation of clock-correction for Detroit, June 29, 1871.

No wires.	Ill.	Star.	C Δ *i*	Aberr.	B *b*	C *c*	*t'*	*α*	(*α*−*t*)	*v*
			s.	*s.*	*s.*	*s.*	*h.* *m.* *s.*	*h.* *m.* *s.*	*m.* *s.*	*s.*
9	W.	β Ursæ Minoris	+.23	−.05	+ .68	+ .13	14 52 32.24	14 51 09.25	−1 23.98	.....
9		β Bootis	−.08	−.02	− .26	+ .04	58 30.83	57 06.62	24.57	+.08
9		β Libræ	−.06	−.01	− .11	+ .04	15 11 29.59	15 10 05.45	24.34	+.13
5		μ^1 Bootis	−.04	−.02	− .23	+ .04	21 02 77	19 38.60	24.46	.00
9		α Serpentis	+.06	−.01	− .16	+ .04	39 20.55	37 56.36	24.44	+.01
9		ε Serpentis	+.06	−.01	− .17	+ .04	45 48.84	44 24.73	24.27	−.15
5		ζ Ursæ Minoris	−.16	−.07	− .88	+ .17	50 10.47	48 47.70	23.91	.....
9		ε Coronæ Borealis	−.04	−.02	− .25	+ .04	53 40.61	52 16.49	24.43	+.02
9		β^1 Scorpii	+.06	−.01	+ .12	+ .04	59 22.05	57 58.00	24.26	−.14
9		δ Ophiuchi	+.06	−.01	+ .17	+ .03	16 08 00.89	16 07 36.81	24.23	−.17
5		τ Herculis	−.05	−.02	− .37	+ .05	17 17.83	15 53.64	24.64	+.26
9		ζ Ophiuchi	+.06	−.01	− .15	+ .04	31 29.14	30 05.15	24.23	−.13
9		ζ Herculis	+.07	−.02	− .29	+ .04	37 51.37	36 27.20	24.55	+.20
9		η Herculis	+.07	−.02	− .29	+ .04	39 54.39	38 30.31	24.46	+.11
9		κ Ophiuchi	+.06	−.01	+ .22	+ .04	52 59.59	51 35.43	24.47	+.14
7	W.	ε Ursæ Minoris	.....	−.10	+1.49	+ .25	17 00 46.86	59 24.69	23.81	.....
5	E.	α^1 Herculis	+.03	−.01	− .13	− .04	10 12.00	17 08 47.70	24.35	+.04
5		α Ophiuchi	+.03	−.01	− .13	− .04	30 22.82	28 58.58	24.29	+.01
5		μ Herculis	+.04	−.02	− .16	− .04	42 50.72	41 26.50	24.28	+.02
5		δ Ursæ Minoris	+.54	−.24	+1.79	− .57	18 15 41.00	18 14 16.93	24.51	.....
5		κ Aquilæ	+.03	−.01	− .12	− .04	19 31 22.83	19 29 58.83	24.04	−.07
5		γ Aquilæ	+.03	−.01	− .13	− .04	41 33.41	40 09.36	24.10	.00
5		α Aquilæ	+.03	−.01	+ .10	− .04	45 55.05	44 31.09	23.98	−.12
3	E.	λ Ursæ Minoris	.....	−.74	+1.79	−1.81	55 41.23	54 17.05	23.42	.....

Normal equations.

$$+1661.89\,a + 125.63\,\rho - 51.00\,\delta\theta + 19.91 = 0$$
$$+ 125.63\,a + 55.18\,\rho + 4.89 = 0$$
$$- 51.00\,a + 24.00\,\delta\theta + 6.02 = 0$$

$a = -0^s.003$.
$c = -0^s.03$, lamp east.
$\rho = -0^s.082$, per hour.
$\Delta t = -1^m\,24^s.33 \pm 0^s.019$, at $16^h\,53^m$.

Austin, Nev., June 16, 1871.

Name of star.	Clamp.	T	*b* B	*a* A	*c* C	T′	AR.	Δ T
		h. m. s.	*s.*	*s.*	*s.*	*h. m. s.*	*h. m. s.*	*m. s.*
η Bootis	E.	13 48 1.08	+0.22	+0.76	−0.36	13 48 1.70	13 48 33.64	+0 31.94
50 Cassiopeæ, L. C.		51 47.76	−0.25	+6.15	+1.08	51 54.74	52 26.22	31.54
a Draconis		14 0 26.42	+0.53	−2.11	−0.80	14 0 24.04	14 0 55.45	31.41
a Bootis		9 15.28	+0.29	+0.74	−0.36	9 15.95	9 47.80	31.85
ι Cassiopeæ, L. C.	W.	17 50.35	−0.12	+5.04	−0.86	17 54.41	18 26.44	32.03
θ Bootis		20 17.51	+0.28	−0.76	+0.56	20 17.59	20 49.86	32.27
5 Ursæ Minoris		27 24.62	+0.58	−5.20	+1.43	27 21.43	27 53.23	31.80
ε Bootis		38 49.72	+0.13	+0.48	+0.38	38 50.71	39 22.56	+0 31.85
Mean for $14^h\,30^m$ local sidereal time								+0 31.936

Normal equations.

$$0 = +0.08 + 8.00\,\delta t - 2.47\,a' - 3.15\,c \qquad \delta t = -0^s.163$$
$$0 = +1.00 + 2.47\,\delta t + 22.68\,a' + 5.92\,c \qquad a' = +0^s.063$$
$$0 = +14.82 - 3.15\,\delta t + 5.99\,a' + 46.35\,c \qquad c = -0^s.339$$

Adopted azimuth $= +2^s.00$; the whole azimuth of the instrument, $a = -2^s.063$.

Austin, Nev., June 16, 1871.

Name of star.	Clamp.	T	*b* B	*a* A	*c* C	T′	AR.	Δ T
		h. m. s.	*s.*	*s.*	*s.*	*h. m. s.*	*h. m. s.*	*m. s.*
θ Sagittarii	E.	19 9 31.40	−0.03	+4.44	−0.36	19 9 35.45	19 10 6.88	+0 31.43
δ Draconis		12 9.85	−0.15	−6.00	−0.89	12 2.81	12 34.46	31.65
δ Aquilæ		18 27.26	−0.06	−2.93	−0.34	18 29.79	19 1.17	31.38
κ Aquilæ		29 23.80	0.00	−3.56	−0.34	29 27.02	29 58.59	31.57
γ Aquilæ		39 35.78	+0.04	+2.39	−0.35	39 37.86	40 9.12	31.26
α Aquilæ		43 57.38	+0.06	+2.54	−0.35	43 59.63	44 30.85	31.22
ε Draconis		48 15.98	+0.25	−7.22	−0.99	48 8.02	48 39.22	+0 31.20
Mean for $19^h\,30^m$ local sidereal time								+0 31.357

Normal equations.

$$0 = -0.55 + 7.00\,\delta t + 0.54\,a' \qquad \delta t = +0^s.08$$
$$0 = +0.68 + 0.54\,\delta t + 5.93\,a' \qquad a' = -0^s.122$$

Adopted azimuth, $+5^s.00$; whole azimuth, $+4^s.878$.

Austin, Nev., June 26, 1871.

Name of star.	Clamp.	T	*b* B	*a* A	*c* C	T	AR.	Δ T
		h. m. s.	*s.*	*s.*	*s.*	*h. m. s.*	*h. m. s.*	*m. s.*
α Draconis	W.	14 0 9.75	+0.91	+13.11	+1.35	14 0 25.12	14 0 55.45	−0 30.33
κ Virginis		5 42.48	−0.25	−9.89	+0.58	5 33.42	6 2.09	29.67
α Bootis		9 22.60	−0.30	−4.60	+0.61	9 18.91	9 47.72	29.81
θ Bootis		20 14.20	+0.58	+4.74	+0.93	20 20.45	20 49.67	29.22
5 Ursæ Minoris		26 47.28	+0.95	+2.44	+2.41	27 23.08	27 52.54	29.46
ε Bootis		38 55.40	+0.29	−32.98	+0.64	38 53.35	39 22.48	29.13
α^2 Libræ	E.	43 27.50	−0.11	−10.93	−0.59	43 16.09	43 46.04	29.95
β Ursæ Minoris		50 13.66	+0.68	+28.08	−2.16	50 40.26	51 9.44	29.18
β Bootis		56 36.80	−0.46	−0.49	−0.37	56 36.88	57 6.68	29.80
β Libræ		15 9 45.84	−0.06	−10.13	−0.56	15 9 35.21	15 10 5.46	30.25
μ^1 Bootis		19 9.85	+0.11	−0.48	−0.72	19 8.76	19 38.19	−0 29.43
Mean for $14^h\,40^m$ local sidereal time								−0 29.675

Normal equations.

$0 = -4.68 + 11.00\,\delta t - 3.09\,a - 2.80\,c \quad \delta t = -0^s.525$
$0 = +42.80 - 3.09\,\delta t + 14.42\,a + 5.64\,c \quad a = -2^s.858$
$0 = +43.17 - 2.80\,\delta t + 5.64\,a + 49.98\,c \quad c = +0^s.570$

Adopted azimuth, $-10^s.00$; whole azimuth of the instrument, $-12^s.858$.

Austin, Nev., June 29, 1871.

Name of star.	Clamp.	T	*b* B	*a* A	*c* C	T	AR.	Δ T
		h. m. s.	*s.*	*s.*	*s.*	*h. m. s.*	*h. m. s.*	*m. s.*
5 Ursæ Minoris..	E.	14 27 40 83	−0.41	−10.64	−1.11	14 27 28.67	14 27 52.32	+0 23.65
π Bootis.....	.....	34 16.22	−0.20	+ 1.83	−0.28	34 17.57	34 41.00	23.43
ε Bootis.....	.....	38 58.40	−0.31	+ 1.05	−0.30	38 58.84	39 22.04	23.20
a^2 Libræ.....	.....	43 19.20	−0.20	+ 3.90	−0.27	43 22.63	43 46.02	23.39
β Ursæ Minoris..	.....	50 57.06	−0.16	−10.00	−1.00	50 45.90	51 9.25	23.35
β Bootis.....	.....	56 43.98	−0.20	− 0.18	−0.40	56 43.20	57 6.62	23.42
48 Cephei, L. C....	W.	15 3 18.96	+0.43	+18.57	−1.19	15 3 36.77	15 3 59.96	23.19
β Libræ.....	.....	9 38.22	−0.22	+ 3.62	+0.27	9 41.89	10 5.45	23.56
γ^2 Ursæ Minoris..	.....	20 45.32	−0.86	− 8.16	+0.87	20 37.17	21 0.04	22.87
α Coronæ.....	.....	28 50.50	−0.35	+ 1.10	+0.29	28 51.54	29 15.07	23.53
α Serpentis.....	.....	37 30.08	−0.34	+ 2.48	+0.27	37 32.49	37 56.36	+0 23.87
Mean for $15^h\ 0^m$ local sidereal time								+0 23.405

Normal equations.

$0 = +1.48 + 11.00\,\delta t + 0.78\,a + 10.86\,c$
$0 = -13.57 + 0.78\,\delta t + 31.61\,a + 2.91\,c \quad a = -0^s.415$
$0 = -15.71 + 10.86\,\delta t + 2.91\,a + 72.60\,c \quad c = -0^s.263$

Adopted azimuth, $+5^s.00$; whole azimuth of the instrument, $+4^s.585$.

The following table shows the corrections and rates for the sidereal chronometer:

Negus 1344.

Date.	Local sidereal time.	Correction of chronometer.	Adopted hourly rate.
	h.	*m. s.*	*s.*
June 16, 1871	17.0	−0 31.612	+0.042
June 26, 1871	14.7	+0 29.475	+0.070
June 29, 1871	15.0	+0 23.405	+0.085

The signals were sent by sound from the mean-time chronometer Hutton No. 288. It was compared with Negus 1344, both before and after exchange. The comparison, June 16, 1871, made before exchange, is:

	h.	*m.*	*s.*	*h.*	*m.*	*s.*
Negus 1344.....	14	45	45.0	14	48	50.0
Hutton 288.....	8	45	37.0	8	48	41.5

and after exchange—

	h.	*m.*	*s.*	*h.*	*m.*	*s.*
Negus 1344.....	18	44	16.0	18	47	20.0
Hutton 288.....	12	43	37.0	12	46	40.5

The hourly rate of Hutton 288, derived from these comparisons, would be $7^s.773$; this first comparison has to be rejected, as there is evidently a mistake in it, as shown by the comparison below. Both chronometers were compared again the next morning.

	h.	*m.*	*s.*
Negus 1344.....	6	44	37.0
Hutton 288.....	0	41	59.5

The rate derived from this comparison and that made after exchange is $9^s.8561$, and is used for the determination of the change of Hutton 288 against sidereal time.

The comparisons of both chronometers on the other dates are as follows:

		h.	m.	s.	h.	m.	s.
June 26, 1871.	Negus 1344	15	38	30.0	15	41	31.0
	Hutton 288	8	58	57.0	9	1	57.5
	After exchange:						
	Negus 1344	13	20	21.0	18	23	24.0
	Hutton 288	11	40	21.0	11	43	23.5
June 29, 1871.	Negus 1344	15	42	12.0	15	45	15.0
	Hutton 288	8	50	44.5	8	53	47.0
	After exchange:						
	Negus 1344	17	30	33.0	17	33	35.0
	Hutton 288	10	38	47.5	10	41	49.0

From these comparisons is derived the data given in the table below.

Hutton 288.

Date.	Hutton's time.	Slow of sidereal time.	Losing per hour.
	h.	h. m. s.	s.
June 16, 1871	12.7524	6 1 10.79	9.8561
June 26, 1871	11.6978	6 40 29.46	9.9820
June 29, 1871	10.6717	6 52 8.94	9.9128

Exchange of signals between Washington, Detroit, and Austin.

JUNE 16, 1871.

Signals sent from Detroit.

Detroit clock.	Austin chronometer.	Detroit clock.	Austin chronometer.	Detroit clock.	Austin chronometer.
h. m. s.	h. m. s.	h. m. s.	h. m. s.	h. m. s.	h. m. s.
18 53 30.16	10 35 12.60	18 56 0.05	10 37 42.10	19 0 0.03	10 41 41.30
40.24	22.70	10.30	52.20		
50.26	32.70	.....	38 0.00	59.97	42 41.10
54 0.30	42.60	.....	.....	1 10.11	51.20
10.22	52.60	.....	40 0.00	20.08	43 1.30
20.21	36 2.60	59	51.60	30.10	11.10
30.08	12.50	10.19	41 1.30	40.22	21.40
55 30.26	37 12.30	19.78	11.70	50.05	31.10
40.08	22.20	30.08	21.60	2 0.07	41.10
50.15	32.20	40.07	31.60	Mean, 18 57 48.53	10 39 30.26
		50.15			

SECOND SERIES.

Detroit clock.	Austin chronometer.	Detroit clock.	Austin chronometer.	Detroit clock.	Austin chronometer.
h. m. s.	h. m. s.	h. m. s.	h. m. s.	h. m. s.	h. m. s.
19 13 0.05	10 54 39.20	19 15 10.17	10 56 49.00	10 17 20.10	10 58 58.50
10.00	49.10	20.20	59.00	30.10	59 8.60
20.23	59.40	30.43	57 9.20	40.28	18.70
30.28	55 9.40	40.17	18.90	50.25	28.60
40.29	19.50	50.10	28.80	59.57	38.00
50.21	29.30	16 0.05	38.70		
59.83	38.90	17 0.00	58 38.70	Mean, 19 15 30.12	10 57 8.90
15 0.00	56 38.90	10.20	48.60		

Signals sent from Austin.

Detroit clock.			Austin chronometer.			Detroit clock.			Austin chronometer.			Detroit clock.			Austin chronometer.		
h.	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*
19	5	20.33	10	47	0.00	19	7	5.85	10	48	47.00	19	8	51.00	10	50	30.00
		25.26			5.00			10.61			50.00			56.00			35.00
		30.24			10.00			15.70			55.00		9	1.22			40.00
		35.32			15.00			20.70		49	0.00			5.95			45.00
		40.31			20.00			25.77			5.00			10.98			50.00
		45.37			25.00			30.61			10.00			15.92			55.00
		50.38			30.00			35.69			15.00			21.00		51	0.00
		55.58			35.00			40.74			20.00			25.99			5.00
	6	0.77			40.00			45.69			25.00			30.90			10.00
		5.71			45.00			50.80			30.00			35.98			15.00
		10.54			50.00			56.00			35.00			41.21			20.00
		15.46			55.00		8	0.95			40.00			46.24			25.00
		20.44		48	0.00			6.00			45.00			51.23			30.00
		25.47			5.00			10.88			50.00			56.26			35.00
		30.34			10.00			15.72			55.00		10	1.28			40.00
		35.60			15.00			20.86		50	0.00			6.00			45.00
		40.47			20.00			25.87			5.00			11.21			50.00
		45.60			25.00			30.78			10.00			16.10			55.00
		50.63			30.00			35.81			15.00			21.10		52	0.00
		55.68			35.00			41.00			20.00						
	7	0.70			40.00			46.00			25.00	Mean, 19	7	50.78	10	49	30.00

Signals sent from Washington.

Washington clock.			Austin chronometer.			Washington clock.			Austin chronometer.			Washington clock.			Austin chronometer.		
h.	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*
20	14	40.00	11	33	36.6	20	15	50.00	11	34	46.2						
		50.00			46.2		16	10.00		35	6.2	20	17	10.00	11	36	6.0
	15	10.00		34	6.3			20.00			16.1			20.00			16.0
		20.00			16.3			30.00			26.0	Mean, 20	16	0.00	11	34	56.16
		30.00			26.4			40.00			36.0						
		40.00			36.0			50.00			46.0						

SECOND SERIES.

Washington clock.			Austin chronometer.			Washington clock			Austin chronometer.			Washington clock.			Austin chronometer.		
h.	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*		*m.*	*s.*	*h.*	*m.*	*s.*
20	35	25.00	11	54	18.1	20	38	25.00	11	57	17.6	20	40	5.00	11	58	57.0
		35.00			27.9			35.00			27.6			15.00		59	7.0
		45.00			38.0			45.00			37.5			25.00			17.0
		55.00			47.9			55.00			47.4			35.00			27.1
	36	5.00			58.0		39	5.00			57.5			45.00			37.0
		15.00		55	7.9			15.00		58	7.4			55.00			47.0
		25.00			18.0			25.00			17.2						
		35.00			27.7			35.00			27.3	Mean, 20	38	15.40	11	57	7.90
		45.00			37.6			45.00			37.2						
		55.00			47.6			.....			.....						

Signals sent from Austin.

Washington clock.			Austin chronometer.			Washington clock.			Austin chronometer.			Washington clock.			Austin chronometer.		
h.	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*		*h.*	*m.*	*s.*	*h.*	*m.*	*s.*
20	21	6.0	11	40	0.00	20	24	36.7	11	43	30.00		20	26	....	11	45	.....
		11.0			5.00			41.7			35.00				41.8			35.00
		15.9			10.00			46.7			40.00				47.0			40.00
		21.0			15.00			51.7			45.00				52.1			45.00
		....			.....			56.4			50.00				56.9			50.00
	22	56.3		41	50.00		25	1.6			55.00			27	1.9			55.00
	23	1.3			55.00			6.4		44	0.00				6.9		46	0.00
		....			.....			11.7			5.00				12.0			5.00
		31.3		42	25.00			16.6			10.00				17.0			10.00
		36.4			30.00			21.7			15.00				21.9			15.00
		...			.....			26.6			20.00				....			.....
		46.6			40.00			31.7			25.00				32.0			25.00
		51.5			45.00			36.7			30.00				37.0			30.00
		56.5			50.00			41.9			35.00				42.0			35.00
		....			.....			....			.....				....			.....
	24	6.3		43	0.00			51.9			45.00				52.0			45.00
		11.2			5.00			56.5			50.00				56.9			50.00
		16.3			10.00		26	1.7			55.00			28	1.8			55.00
		21.4			15.00			6.6		45	0.00				7.0		47	0.00
		26.6			20.00			11.7			5.00							
		31.6			25.00			16.6			10.00	Mean,	20	25	19.37	11	44	12.74

Signals sent from Austin.

Washington clock.			Austin chronometer.			Washington clock.			Austin chronometer.			Washington clock.			Austin chronometer.		
h.	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*		*h.*	*m.*	*s.*	*h.*	*m.*	*s.*
20	48	10.3	12	7	0.00	20	48	50.5	12	7	40.00		20	49	30.5	12	8	20.00
		15.3			5.00			55.5			45.00				35.5			25.00
		20.2			10.00		49	0.5			50.00				40.4			30.00
		25.2			15.00			5.5			55.00				45.5			35.00
		30.4			20.00			10.3		8	0.00				50.6			40.00
		35.3			25.00			15.3			5.00							
		40.3			30.00			20.6			10.00	Mean,	20	49	0.41	12	7	50.00
		45.4			35.00			25.5			15.00							

Signals sent from Austin.

Washington clock.			Austin chronometer.			Washington clock.			Austin chronometer.			Washington clock.			Austin chronometer.		
h.	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*		*h.*	*m.*	*s.*	*h.*	*m.*	*s.*
20	57	11.9	12	16	0.00	20	58	32.0	12	17	20.00		20	59	52.3	12	18	40.00
		16.9			5.00			....			.....				57.7			45.00
		21.8			10.00			42.1			30.00		21	0	2.4			50.00
		26.8			15.00			47.0			35.00				7.3			55.00
		32.0			20.00			52.1			40.00				12.4		19	0.00
		36.9			25.00			....			.....				....			.....
		41.8			30.00		59	2.4			50.00				22.2			10.00
		46.8			35.00			7.3			55.00				27.2			15.00
		52.0			40.00			12.2		18	0.00				32.4			20.00
		57.0			45.00			17.2			5.00				37.3			25.00
	58	2.1			50.00			22.1			10.00				42.3			30.00
		7.0			55.00			.....			.....				47.4			35.00
		12.0		17	0.00			32.2			20.00							
		17.0			5.00			37.2			25.00	Mean,	20	58	57.63	12	17	45.50
		22.0			10.00			42.1			30.00							
		27.0			15.00			47.3			35.00							

JUNE 26, 1871.

Signals sent from Detroit.

Detroit clock.			Austin chronometer.			Detroit clock.			Austin chronometer.			Detroit clock.			Austin chronometer.		
h.	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*		*h.*	*m.*	*s.*	*h.*	*m.*	*s.*
19	43	0.19	10	45	9.6	19	43	50.00	10	45	59.3		19	59	0.39	16	1	7.2
		.....			....		44	0.00		46	9.2							
		19.87			29.2							Mean,	19	48	39.04	10	50	47.57
		30.00			39.4		58	40.35	11	0	47.3							
		40.00			49.5			50.54			57.4							

SECOND SERIES.

Detroit clock.			Austin chronometer.			Detroit clock.			Austin chronometer.			Detroit clock.			Austin chronometer.		
h.	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*		*h.*	*m.*	*s.*	*h.*	*m.*	*s.*
20	9	0.00	11	11	5.2	20	9	59.98	11	12	5.1		20	11	40.10	11	13	44.9
		10.00			15.1										50.19			55.0
		20.20			25.2		11	0.00		13	5.0				59.73		14	4.8
		30.00			35.2			10.27			15.0							
		40.51			45.4			20.18			25.0	Mean,	20	10	30.11	11	12	35.09
		50.20			55.4			30.13			35.0							

Signals sent from Austin.

Detroit clock.			Austin chronometer.			Detroit clock.			Austin chronometer.			Detroit clock.			Austin chronometer.		
h.	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*		*h.*	*m.*	*s.*	*h.*	*m.*	*s.*
20	0	55.49	11	3	0.00	20	2		11	4	.....		20	4	24.74	11	6	30.00
		.....						.....		5	.....				29.92			35.00
	1	4.60			10.00			49.87			55.00				35.00			40.00
		9.58			15.00			54.91			0.00				40.00			45.00
		14.79			20.00			59.90			5.00				45.17			50.00
		19.77			25.00		3	.....			.....				49.89			55.00
		24.69			30.00			.....			.....				55.15		7	0.00
		29.78			35.00			.....			.....				.....			.....
		34.82			40.00			.....			.....			5	5.00			10.00
		39.68			45.00			25.00			30.00				10.18			15.00
		44.63			50.00			29.91			35.00				15.20			20.00
		49.85			55.00			34.95			40.00				20.10			25.00
		54.92		4	0.00			39.89			45.00				25.00			30.00
		59.61			5.00			44.93			50.00				30.21			35.00
	2	4.79			10.00			49.71			55.00				35.21			40.00
		9.90			15.00			54.81		6	0.00				40.39			45.00
		14.64			20.00			59.92			5.00				45.47			50.00
		19.61			25.00		4	4.91			10.00				50.43			55.00
		24.93			30.00			10.00			15.00				55.48		8	0.00
		.....			.....			14.80			20.00							
		.....			.....			19.87			25.00	Mean,	20	3	30.63	11	5	35.69

JUNE 29, 1871.

Signals sent from Detroit.

Detroit clock.			Austin chronometer.			Detroit clock.			Austin chronometer.			Detroit clock.			Austin chronometer.		
h.	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*		*h.*	*m.*	*s.*	*h.*	*m.*	*s.*
18	54	0.00	9	44	34.2	18	56	10.31	9	46	43.9		18	58	20.24	9	48	53.6
		10.11			44.0			20.18			53.8				30.19		49	3.5
		20.17			54.1			30.21		47	3.6				40.21			13.5
		30.20		45	4.2			40.37			13.8				50.20			23.4
		40.12			14.0			50.09			23.6			59	0.18			33.4
		50.42			24.2		57	0.29			33.7							
	55	0.16			34.2							Mean,	18	56	30.19	9	47	3.78
							58	0.15		48	33.5							
	56	0.00		46	33.8			10.19			43.4							

SECOND SERIES.

Detroit clock.			Austin chronometer.			Detroit clock.			Austin chronometer.			Detroit clock.			Austin chronometer.		
h.	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*		*h.*	*m.*	*s.*	*h.*	*m.*	*s.*
19	10	0.38	10	0	31.6	19	12	10.26	10	2	41.0		19	[illegible]	20.21	10	6	50.5
		10.32			41.5			20.17			51.1				30.30		7	0.6
		20.12			51.6			30.20		3	1.0				40.20			10.5
		30.23		1	1.6			40.21			11.0				50.00			20.4
		40.16			11.5			50.22			21.1			17	0.32			30.5
		50.25			21.6		13	0.18			31.1							
	11	0.27			31.5								Mean, 19	13	10.23	10	3	41.06
							16	0.28		6	30.7							
	12	0.27		2	31.3			10.20			40.5							

Signals sent from Austin.

Detroit clock.			Austin chronometer.			Detroit clock.			Austin chronometer.			Detroit clock.			Austin chronometer.		
h.	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*		*h.*	*m.*	*s.*	*h.*	*m.*	*s.*
19	1	27.99	9	52	0.00	19	3	13.13	9	53	45.00		19	4	58.43	9	55	30.00
		32.98			5.00			18.27			50.00			5	3.47			35.00
		37.83			10.00			23.32			55.00				8.42			40.00
		43.00			15.00			28.46		54	0.00				13.55			45.00
		48.18			20.00			33.37			5.00				18.67			50.00
		53.00			25.00			38.29			10.00				23.63			55.00
		58.10			30.00			43.26			15.00				28.77		56	0.00
	2	2.93			35.00			48.27			20.00				33.76			5.00
		8.00			40.00			53.25			25.00				38.48			10.00
		13.00			45.00			58.42			30.00				43.70			15.00
		18.16			50.00		4	3.52			35.00				48.79			20.00
		23.10			55.00			8.45			40.00				53.64			25.00
		28.00		53	0.00			13.46			45.00				58.72			30.00
		33.23			5.00			18.45			50.00			6	3.80			35.00
		38.00			10.00			23.35			55.00				8.85			40.00
		43.00			15.00			28.65		55	0.00				13.79			45.00
		48.00			20.00			33.66			5.00				18.73			50.00
		53.10			25.00			38.41			10.00				23.83			55.00
		58.22			30.00			43.35			15.00				28.84		57	0.00
	3	3.26			35.00			48.45			20.00							
		8.24			40.00			53.58			25.00		Mean, 19	3	58.37	9	54	30.00

Deduction of results for longitude of Austin, Nev.

Date.	Signals sent from—	Detroit clock.	Correction of Detroit clock.	Local sidereal time of the mean of signals.	Austin chronometer.	Correction of Austin chronometer.	Local sidereal time of the mean of signals.	Differences of longitude.	Means.	Double-wave time.	Final differences of longitude.
1871.		*h. m. s.*	*m. s.*	*h. m. s.*	*h. m. s.*	*h. m. s.*	*h. m. s.*	*h. m. s.*	*s.*	*s.*	*h. m. s.*
June 16	Detroit to Austin	18 57 48.53	−1 26.01	18 56 22.52	10 39 30.36	+6 0 50.15	16 40 20.41	2 16 2.11			
16	Detroit to Austin	19 15 30.12	26.02	19 14 4.10	10 57 8.90	53.05	16 58 1.95	2.15	2.13		
16	Austin to Detroit	19 7 50.78	26.01	19 6 24.77	10 49 30.00	51.79	16 50 21.79	2.98	2.98	0.85	2 16 2.55
26	Detroit to Austin	19 48 39.04	−1 28.45	19 47 10.59	10 50 47.57	+6 40 20.98	17 31 8.55	2.04			
26	Detroit to Austin	20 10 30.11	28.43	20 9 1.68	11 12 35.09	24.60	17 52 59.69	1.99	2.01		
26	Austin to Detroit	20 3 30.63	28.43	20 2 2.20	11 5 35.69	23.44	17 45 59.13	3.07	3.07	1.06	2.54
29	Detroit to Austin	18 56 30.19	−1 24.17	18 55 6.02	9 47 3.78	+6 52 0.14	16 39 3.92	2.10			
29	Detroit to Austin	19 13 10.23	24.14	19 11 46.09	10 3 41.06	2.89	16 55 43.95	2.14	2.12		
29	Austin to Detroit	19 3 58.37	24.16	19 2 34.21	9 54 30.00	1.37	16 46 31.37	2.84	2.84	0.72	2.48

Austin west of Detroit, $2^h\ 16^m\ 2^s.52 \pm 0^s.015$.

Determination of longitude between Washington, D. C., and Austin, Nev.

June 16, 1871.	Mean of signals sent and received.	Time correction.	Corrected time.	Difference of longitude.	Means.
	h. m. s.	h. m. s.	h. m. s.	h. m. s.	h. m. s.
Washington clock	20 16 0.00	−0 0 2.27	20 15 57.73		
Austin chronometer	11 34 56.16	+6 0 59.26	17 35 55.42	2 40 2.31	
Washington clock	20 38 15.40	−0 0 2.28	20 38 13.12		
Austin chronometer	11 57 7.90	+6 1 2.90	17 58 10.80	2 40 2.32	2 40 2
Austin chronometer	11 44 12.74	+6 1 0.78	17 45 13.52		
Washington clock	20 25 19.37	−0 0 2.28	20 25 17.09	2 40 3.57	
Austin chronometer	12 7 50.00	+6 1 4.65	18 8 54.65		
Washington clock	20 49 0.41	−0 0 2.28	20 48 58.13	2 40 3.48	
Austin chronometer	12 17 45.50	+6 1 6.29	18 18 51.79		
Washington clock	20 58 57.63	−0 0 2.28	20 58 55.35	2 40 3.56	2 40 3

Austin, Nev., west of Washington, D. C., 2*h*. 40*m*. 2.93*s*.

Mean places of stars for 1871 *used for determination of latitude of Austin, Nev.*

No. of pair.	No. in B. A. C.	Declination.	No. of pair.	No. in B. A. C.	Declination.
		° ′ ″			° ′ ″
	4847	16 58 22.31		5693	31 55 0.47
1	4874	61 48 45.81	11	5706	46 44 55.94
	4905	19 38 14.45	12	5740	65 19 54.64
2	4918	59 49 7.80	13	5745	65 14 7.35
				5753	13 47 26.25
	4980	48 39 1.13		5757	13 45 18.36
3	5001	29 43 14.44			
				5785	54 38 26.40
	5075	30 45 18.71	14	5798	24 23 49.00
4	5113	48 9 26.29			
				5863	32 38 9.99
	5259	36 3 33.20	15	5871	46 22 6.04
5	5271	42 48 48.95			
				5900	20 11 30.49
	5319	33 41 43.38	16	5918	58 45 37.83
6	5388	45 16 26.88			
				5951	55 15 38.97
	5426	19 8 8.60	17	5967	24 23 18.74
7	5459	60 4 6.27			
				6021	27 47 52.65
	5480	34 0 16.80	18	6052	50 48 45.30
8	5497	44 59 9.56			
				6087	30 12 5.28
	5568	46 52 31.27	19	6129	48 27 33.22
9	5604	31 50 17.80			
				6162	43 26 50.67
	5628	64 50 1.62	20	6235	36 0 27.75
10	5647	13 29 20.80			

Observations for latitude.—Station, Austin, Nev.

JUNE 15, 1871.

No. of star.	Micrometer-readings.	Level. N.	Level. S.	Remarks.	No. of star.	Micrometer-readings.	Level. N.	Level. S.	Remarks.
	t. d.	*d.*	*d.*			*t. d.*	*d.*	*d.*	
4847	12 9.1	14.0	11.8		5740	12 18.2			
4874	20 61.6	12.2	13.6		5745	16 48.1	16.8	11.0	
					5753	18 48.5			
4905	26 80.8	14.0	12.0		5757	16 93.4	6.5	21.5	
4918	5 12.5	13.2	12.5						
					5785	12 69.7	15.8	12.5	
5075	16 41.2	13.3	13.0		5798	15 38.0	11.5	16.5	
5113	19 25.6	12.5	13.8						
					5863	18 41.1	12.8	15.7	
5319	13 80.2	13.8	13.0		5871	17 27.4	14.2	14.0	
5388	14 21.0	12.0	15.0						
					5900	20 10.6	13.0	15.0	
5426	25 88.2	10.5	16.8		5918	21 22.4	14.5	14.0	
5459	15 76.7	15.0	12.0						
					6021	11 19.6	13.5	15.0	
5480	19 95.0	13.3	14.9		6052	27 67.7	13.0	15.6	
5497	19 36.2	12.2	15.4						
					6087	15 27.5	14.0	14.8	
5568	24 99.9	12.5	15.7		6129	29 49.6	11.2	17.2	
5604	13 19.5	14.0	14.4						
					6162	7 45.0	12.5	16.2	
5628	34 57.9	11.8	16.8		6235	28 60.0	16.5	12.8	
5647	5 50.3	16.0	12.5						
5693	8 75.0	14.5	13.8						
5706	22 49.2	18.8	9.3						

JUNE 17, 1871.

No. of star.	Micrometer-readings.	Level. N.	Level. S.	Remarks.	No. of star.	Micrometer-readings.	Level. N.	Level. S.	Remarks.
	t. d.	*d.*	*d.*			*t. d.*	*d.*	*d.*	
4905	26 3.7	14.0	12.0		5740	11 61.0			
4918	4. 77.6	9.0	17.0		5745	15 92.5	13.0	16.9	
					5753	18 10.2			
4980	33 38.7	13.8	12.8		5757	16 56.3	16.5	13.5	
5001	6 60.6	15.3	10.8						
					5785	13 36.7	14.0	15.8	
5075	16 98.4	2.0	25.0	Must be 68.4.	5798	15 94.4	13.7	16.3	
5113	19 51.5	22.0	5.2						
					5863	19 39.4	17.0	12.8	
5319	13 63.6	13.0	15.8		5871	18 30.0	12.3	17.2	
5388	14 7.8	12.0	17.2						
					5900	21 13.8	15.8	14.8	
5426	26 81.0	15.2	12.8		5918	22 31.6	11.8	17.8	
5459	16 71.8	11.5	17.8						
					6021	11 41.3	11.2	17.2	
5480	20 15.2	13.8	16.0		6052	27 84.8	15.8	12.8	
5497	19 59.5	13.7	15.6						
					6087	14 61.7	13.0	15.0	
5568	24 22.3	15.5	14.2	Must be 24.3.	6129	28 87.9	11.2	16.2	
5604	12 27.9	16.0	14.0	Excl.					
					6162	6 89.4	12.2	14.6	
5628	34 42.7	8.5	21.2		6235	27 92.7	9.8	16.5	
5647	5 15.5	20.2	9.3						

Observations for latitude.—Station, Austin, Nev.—Continued.

JUNE 21, 1871.

No. of star.	Micrometer-readings.	Level. N.	Level. S.	Remarks.	No. of star.	Micrometer-readings.	Level. N.	Level. S.	Remarks.
	t. d.	*d.*	*d.*			*t. d.*	*d.*	*d.*	
5568	24 75.3	14.8	17.8		5863	18 91.4	16.0	17.2	
5604	17 97.6	17.2	15.5	Must be 12'.	5871	17 81.9	14.9	18.5	
5628	34 59.7	11.7	21.2		5900	22 20.0	16.4	17.0	
5647	5 40.2	21.2	11.5		5918	23 35.9	14.7	18.7	
5693	9 37.0	16.8	16.0		5951	4 81.0	17.0	16.5	
5706	23 29.1	15.0	17.7		5967	34 71.4	16.8	17.0	
5740	12 83.3	14.7	18.0		6021	11 34.5	17.5	16.1	
5745	17 2.9				6052	27 75.1	14.0	19.6	
5753	19 27.4	18.1	15.0						
5757	17 69.7				6087	14 63.7	17.5	16.3	
					6129	28 78.7	15.9	18.0	
5785	13 51.2	15.7	17.2						
5798	16 21.3	16.2	17.0		6162	7 73.0	15.9	18.1	
					6235	28 95.0	19.8	14.0	

JUNE 23, 1871.

No. of star.	Micrometer-readings.	Level. N.	Level. S.	Remarks.	No. of star.	Micrometer-readings.	Level. N.	Level. S.	Remarks.
	t. d.	*d.*	*d.*			*t. d.*	*d.*	*d.*	
5259	16 5.5	15.5	16.0		5480	20 86.2	20.8	12.5	
5271	20 65.4	15.2	17.0		5497	20 33.4	8.8	24.5	
5319	13 86.7	14.5	18.0		5568	25 29.5	16.5	17.0	
5388	14 31.9	14.2	19.0		5604	13 47.9	12.0	21.0	
5426	26 49.9	12.8	20.5		5628	34 25.0	13.8	19.5	
5459	16 45.5	17.5	15.5		5647	5 4.1	14.5	18.8	

Computations for latitude of Austin, Nev.

Date.	No. of pair.	Half-sum of declination.	Corrections. Micr. and refr.	Corrections. Level.	Corrections. Merid.	Latitude.
		° ′ ″	′ ″	″		° ′ ″
June 15, 1871	1	39 23 40.78	+ 5 44.77	+0.54	.....	39 29 26.09
	2	43 47.75	−14 36.93	+1.82	.....	22.64
	4	27 28.27	+ 1 55.01	−0.67	.....	22.61
	6	29 9.43	+ 0 16.50	−1.48	.....	24.45
	7	36 10.96	− 6 49.06	−2.23	.....	19.67
	8	29 46.70	− 0 23.78	−2.77	.....	20.15
	9	21 27.37	+ 7 57.37	−2.43	.....	22.31
	10	9 43.52	+19 35.97	−1.01	.....	20.48
	11	20 0.40	+ 9 15.75	+6.88	.....	23.03
	12	33 42.18	− 4 14.91	−6.21	.....	18.94
	13	29 44.56	− 0 18.31	−6.21	.....	20.04
	14	31 9.20	− 1 48.50	−1.15	.....	19.55
	15	30 8.97	− 0 45.98	−1.82	.....	21.17
	16	28 34.74	+ 0 45.22	−1.01	.....	18.95
	18	18 18.66	+11 6.53	−2.77	.....	22.42
	19	19 48.31	+ 9 35.12	−4.59	.....	18.84
	20	43 37.46	−14 15.35	0.00	.....	22.11

Signals sent from Austin.

Detroit clock.			Austin chronometer.			Detroit clock.			Austin chronometer.			Detroit clock.			Austin chronometer.		
h.	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*		*h.*	*m.*	*s.*	*h.*	*m.*	*s.*
19	5	20.33	10	47	0.00	19	7	5.85	10	48	47.00		19	8	51.00	10	50	30.00
		25.26			5.00			10.61			50.00				56.00			35.00
		30.24			10.00			15.70			55.00			9	1.22			40.00
		35.32			15.00			20.70		49	0.00				5.95			45.00
		40.31			20.00			25.77			5.00				10.98			50.00
		45.37			25.00			30.61			10.00				15.92			55.00
		50.38			30.00			35.69			15.00				21.00		51	0.00
		55.58			35.00			40.74			20.00				25.99			5.00
	6	0.77			40.00			45.69			25.00				30.90			10.00
		5.71			45.00			50.80			30.00				35.98			15.00
		10.54			50.00			56.00			35.00				41.21			20.00
		15.46			55.00		8	0.95			40.00				46.24			25.00
		20.44		48	0.00			6.00			45.00				51.23			30.00
		25.47			5.00			10.88			50.00				56.26			35.00
		30.34			10.00			15.72			55.00			10	1.28			40.00
		35.60			15.00			20.86		50	0.00				6.00			45.00
		40.47			20.00			25.87			5.00				11.21			50.00
		45.60			25.00			30.78			10.00				16.10			55.00
		50.63			30.00			35.81			15.00				21.10		52	0.00
		55.68			35.00			41.00			20.00							
	7	0.70			40.00			46.00			25.00	Mean,	19	7	50.78	10	49	30.00

Signals sent from Washington.

Washington clock.			Austin chronometer.			Washington clock.			Austin chronometer.			Washington clock.			Austin chronometer.		
h.	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*		*h.*	*m.*	*s.*	*h.*	*m.*	*s.*
20	14	40.00	11	33	36.6	20	15	50.00	11	34	46.2		20	17	10.00	11	36	6.0
		50.00			46.2		16	10.00		35	6.2				20.00			16.0
	15	10.00		34	6.3			20.00			16.1							
		20.00			16.3			30.00			26.0	Mean,	20	16	0.00	11	34	56.16
		30.00			26.4			40.00			36.0							
		40.00			36.0			50.00			46.0							

SECOND SERIES.

Washington clock.			Austin chronometer.			Washington clock			Austin chronometer.			Washington clock.			Austin chronometer.		
h.	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*		*h.*	*m.*	*s.*	*h.*	*m.*	*s.*
20	35	25.00	11	54	18.1	20	38	25.00	11	57	17.6			*m.*	*s.*	*h.*	*m.*	*s.*
		35.00			27.9			35.00			27.6		20	40	5.00	11	58	57.0
		45.00			38.0			45.00			37.5				15.00		59	7.0
		55.00			47.9			55.00			47.4				25.00			17.0
	36	5.00			58.0		39	5.00			57.5				35.00			27.1
		15.00		55	7.9			15.00		58	7.4				45.00			37.0
		25.00			18.0			25.00			17.2				55.00			47.0
		35.00			27.7			35.00			27.3	Mean,	20	38	15.40	11	57	7.90
		45.00			37.6			45.00			37.2							
		55.00			47.6			.....			.....							

when the station was occupied by the astronomer. As far as can be learned from the diary, the nights were pretty clear, and the condition of the air very favorable for astronomical observations. In 1872 some barometric observations were taken to determine the altitude of the place.

The astronomical observations were taken in a common wall-tent, as at the other stations. Mr. A. R. Marvine, the observer, was assisted by a recorder and two soldiers, and Mr. E. P. Austin had charge of the Salt Lake observatory, the use of which was kindly tendered by President Brigham Young, of the Mormon church. Through him the use of the Deseret Telegraph line, for exchange of signals, was secured. The wires were brought into the tent by a loop.

The astronomical instruments used at St. George were the combined transit, used before by Assistant E. P. Austin, in Nevada, and the sidereal chronometer, Negus No. 1344. The Salt Lake instrument belonged to President Young, and was used by a Coast-Survey party, and by the expeditions of 1872 and 1873. All the data relating to this instrument will be found in the general report for 1873 by J. H. Clark.

Hutton mean-time chronometer No. 288 was used for the determination of time. All the observations were taken by eye and ear, and the exchange of signals made by sound.

Connection was made, as stated, with Salt Lake observatory. Exchanges of signals were effected on the nights of September 13, 14, and 15, 1871.

The observations at both stations were compared in 1873 by Dr. F. Kampf, and rereduced in 1874, when this report was made up by him.

The instrumental values for the St. George instruments will be found in the Carlin report, and those for the Salt Lake transit in J. H. Clark's general report for 1873. The telegraphic line is three hundred miles long, and the signals were transferred direct, without repeaters. The discrepancy between the results for longitude on the first and second days is very remarkable, but too large on the second day to take into the final result. It may be that this change is an example of rapid variation in personal equation.

Salt Lake City, September 13, 1871.

Name of star.	Clamp.	T	*b*B	*a*A	*c*C	T′	AR.	ΔT
		h. *m.* *s.*	*s.*	*s.*	*s.*	*h.* *m.* *s.*	*h.* *m.* *s.*	*h.* *m.* *s.*
ι Lyræ	W.	6 54 12.09	−0.33	0.00	+0.02	6 54 11.78	18 32 35.48	+11 38 23.70
β Lyræ	....	7 6 56.94	−0.26	+0.02	+0.02	7 6 56.72	45 20.37	23.65
50 Draconis	....	12 9.50	−0.65	−0.22	+0.06	12 8.63	50 32.36	23.73
ζ Aquilæ	....	21 6.88	−0.22	+0.06	+0.02	21 6.74	59 30.33	23.59
δ Draconis	....	34 9.65	−0.40	−0.15	+0.04	34 9.14	19 12 32.64	23.50
δ Aquilæ	E.	40 37.59	−0.17	+0.08	−0.02	40 37.48	19 1.31	23.83
κ Aquilæ	....	51 35.09	−0.15	+0.09	−0.02	51 35.01	29 58.86	23.85
Aquilæ	....	8 1 45.70	−0.20	+0.07	−0.02	8 1 45.55	40 9.35	23.80
ε Draconis	....	10 14.64	−0.34	−0.18	−0.05	10 14.07	48 37.84	+11 38 23.77
Mean for 7h.5369 Hutton's time								+11 38 23.713

Normal equations.

$$0 = +0.12 + 9.00\,\delta t - 1.25\,a - 4.10\,c \qquad \delta t = +0^s.013$$
$$0 = -1.35 - 1.25\,\delta t + 9.79\,a + 8.84\,c \qquad a = +0^s.125$$
$$0 = -1.66 - 4.10\,\delta t + 8.84\,a + 38.01\,c \qquad c = -0^s.016$$

Salt Lake City, September 13, 1871.

Name of star.	Clamp.	T	*b* B	*a* A	*c* C	T′	AR.	Δ T
		h. m. s.	*s.*	*s.*	*s.*	*h. m. s.*	*h. m. s.*	*h. m. s.*
ε Pegasi	W.	9 59 2.53	− 0.06	+ 0.13	+ 0.02	9 59 2.62	21 37 53.24	+11 38 50.62
μ Capricorni		10 7 27.46	− 0.02	+ 0.21	+ 0.02	10 7 27.67	46 18.06	50.39
79 Draconis		12 29.62	0.00	− 0.44	+ 0.06	12 29.24	51 19.74	50.50
α Aquarii		20 20.91	− 0.06	+ 0.16	+ 0.02	20 21.03	59 11.74	+11 38 50.71
Mean for 10ʰ.1616 Hutton's time								+11 38 50.555

Normal equations.

$0 = +0.52 + 4.00\,\delta t + 0.24\,a$ $\qquad \delta t = -0^s.145$

$0 = -1.23 + 0.24\,\delta t + 4.69a$ $\qquad a = +0^s.238$

Adopted $c = -0^s.016$. It is not possible to solve normal equations if factors for c are introduced.

Salt Lake City, September 14, 1871.

Name of star.	Clamp.	T	*b* B	*a* A	*c* C	T′	AR.	Δ T
		h. m. s.	*s.*	*s.*	*s.*	*h. m. s.*	*h. m. s.*	*h. m. s.*
δ Draconis	W.	7 30 7.07	0.00	− 0.32	+ 0.05	7 30 6.80	19 12 32.59	+11 42 25.79
δ Aquilæ		36 35.50	− 0.04	+ 0.17	+ 0.02	36 35.65	19 1.29	25.64
κ Aquilæ		47 32.92	0.00	+ 0.21	+ 0.02	47 33.15	29 58.84	25.69
γ Aquilæ	E.	57 43.50	+ 0.06	+ 0.14	− 0.02	57 43.68	40 9.33	25.65
α Aquilæ		8 2 5.16	+ 0.06	+ 0.15	− 0.02	8 2 5.35	44 31.12	25.77
ε Draconis		6 12.38	+ 0.20	− 0.39	− 0.06	6 12.13	48 37.78	25.65
τ Aquilæ		15 26.03	+ 0.07	+ 0.16	− 0.02	15 26.24	57 52.12	+11 42 25.88
Mean for 7ʰ.8796 Hutton's time 288								+11 42 25.724

Normal equations.

$0 = +0.41 + 7.00\,\delta t + 0.41\,a$ $\qquad \delta t = -0^s.076$

$0 = -1.41 + 0.41\,\delta t + 5.18\,a$ $\qquad a = +0^s.278$

Error of collimation found by preliminary reduction $= -0^s.02$.

Salt Lake City, September 14, 1871.

Name of star.	Clamp.	T	*b* B	*a* A	*c* C	T′	AR.	Δ T
		h. m. s.	*s.*	*s.*	*s.*	*h. m. s.*	*h. m. s.*	*h. m. s.*
ξ Aquarii	E.	9 48 06.08	−0.14	+0.16	−0.02	9 48 06.08	21 30 55.26	+11 42 49.18
11 Cephei		57 16.36	−0.10	−0.31	−0.06	57 15.89	40 05.01	49.12
μ Capricorni		10 03 28.76	−0.02	+0.18	−0.02	10 03 28.90	46 18.05	49.15
79 Draconis	W.	08 30.76	0.00	−0.38	+0.07	08 30.45	51 19.71	49.26
α Aquarii		16 22.57	−0.04	+0.14	+0.02	16 22.69	59 11.74	49.05
θ Aquarii		27 14.42	−0.10	+0.16	+0.02	27 14.50	22 10 03.89	+11 42 49.39
Mean for 10ʰ.1279 Hutton 288								+11 42 49.192

Normal equations.

$0 = +0.07 + 6.00\,\delta t - 0.27\,a$ $\qquad \delta t = -0^s.108$

$0 = -1.69 - 0.27\,\delta t + 8.06\,a$ $\qquad a = +0^s.206$

Adopted $c = -0^s.02$

Salt Lake City, September 15, 1871.

Name of star.	Clamp.	T	*b* B	*a* A	*c* C	T′	AR.	Δ T
		h. m. s.	*s.*	*s.*	*s.*	*h. m. s.*	*h. m. s.*	*h. m. s.*
1 Aquilæ	W.	6 41 51.86	+0.03	+0.23	+0.02	6 41 52.14	18 28 12.71	+11 46 20.57
α Lyræ		46 15.03	0.00	+0.01	+0.63	46 15.07	32 35.43	20.36
β Lyræ		58 59.85	−0.06	+0.05	+0.02	58 59.86	45 20.32	20.46
50 Draconis		7 04 12.47	−0.10	−0.69	+0.08	7 04 11.76	50 32.17	20.41
ζ Aquilæ		13 09.94	−0.05	+0.15	+0.02	13 10.06	59 30.29	20.23
δ Draconis	E.	26 12.37	+0.12	−0.36	−0.05	26 12.08	19 12 32.52	20.44
δ Aquilæ		32 40.70	+0.04	+0.19	−0.02	32 40.91	19 01.27	20.36
κ Aquilæ		43 38.21	+0.02	+0.23	−0.02	43 38.44	29 58.83	20.39
γ Aquilæ		53 48.70	+0.03	+0.16	−0.02	53 48.87	40 09.32	20.45
α Aquilæ		58 10.48	+0.03	+0.17	−0.02	58 10.66	44 31.11	+11 46 20.45
Mean for 7h 3337 Hutton 288								+11 46 20.412

Normal equations.

$0 = +1.74 + 10.00\,\delta t + 0.47\,a$ $\qquad \delta t = -0^s.188$

$0 = -2.59 + 0.47\,\delta t + 8.67\,a$ $\qquad a = +0^s.309$

Adopted $c = -0^s.02$

Salt Lake City, September 15, 1871.

Name of star.	Clamp.	T	*b* B	*a* A	*c* C	T′	AR	Δ T
		h. m. s.	*s.*	*s.*	*s.*	*h. m. s.*	*h. m. s.*	*h. m. s.*
ξ Aquarii	E.	9 44 5.42	+ 0.03	+ 0.27	− 0.02	9 44 5.70	21 30 55.25	+11 46 49.55
11 Cephei		53 15.48	+ 0.42	− 0.53	− 0.06	53 15.31	40 04.97	49.66
μ Capricornii		59 27.96	+ 0.03	+ 0.31	− 0.02	59 28.28	46 18.04	49.76
α Aquarii	W.	10 12 21.94	− 0.04	+ 0.23	+ 0.02	10 12 22.15	59 11.74	49.59
θ Aquarii		23 13.93	+ 0.03	+ 0.27	+ 0.02	23 14.25	22 10 03.88	49.63
π Aquarii		31 53.79	+ 0.03	+ 0.22	+ 0.02	31 54.06	18 43.63	49.57
226 Cephei		43 15.74	+ 0.45	− 0.92	+ 0.09	43 15.36	30 04.97	+11 46 49.61
Mean for 10h.2278 Hutton's time								+11 46 49.624

Normal equations.

$0 = -0.72 + 7.00\,\delta t - 0.43\,a$ $\qquad \delta t = +0^s.124$

$0 = -4.15 - 0.43\,\delta t + 12.05\,a$ $\qquad a = +0^s.349$

Adopted $c = -0^s.02$

St. George, Utah, September 13, 1871.

Name of star.	Clamp.	T	*b* B	*a* A	*c* C	T′	AR.	Δ T
		h. m. s.	*s.*	*s.*	*s.*	*h. m. s.*	*h. m. s.*	*m. s.*
α Sagitarii	W.	19 06 04.44	− 0.11	− 0.13	+ 0.42	19 06 04.62	19 10 07.05	+ 4 02.43
τ Draconis		14 00.18	− 1.39	+ 0.29	+ 1.28	14 00.36	18 02.76	02.40
κ Aquilæ		25 56.62	− 0.43	− 0.10	+ 0.40	25 56.49	29 58.86	02.37
β Aquilæ	E.	44 58.83	− 0.34	− 0.03	− 0.40	44 58.06	49 00.40	02.34
τ Aquilæ		53 50.47	− 0.18	− 0.03	− 0.41	53 49.85	57 52.14	02.29
κ Cephei		20 09 15.02	− 1.53	+ 0.18	− 1.82	20 09 11.85	20 13 14.25	02.40
π Capricorni		15 56.56	− 0.32	− 0.05	− 0.42	15 55.77	19 58.30	02.53
ε Delphini		23 03 52	− 0.52	− 0.03	− 0.41	23 02.56	27 04.92	+ 4 02.36
Mean for 19h 40m local sidereal time								+ 4 02.39

The azimuth of the instrument is changed after reversing. The error of collimation is derived by preliminary computation, $= -0^s.40$; and the azimuth determined for both positions separately.

Normal equations.

For clamp west: $0 = -0.06 + 3.00\,\delta t - 0.44\,a$ $\qquad \delta t = 0^s.000$

$0 = +0.78 - 0.44\,\delta t + 5.39\,a$ $\qquad a = -0^s.145$

For clamp east: $0 = +0.04 + 5.00\,\delta t - 0.59\,a$ $\qquad \delta t = -0^s.01$

$0 = +0.61 - 0.59\,\delta t + 10.13\,a$ $\qquad a = -0^s.060$

St. George, Utah, September 13, 1871.

	Name of star.	Clamp.	T	*b* B	*a* A	*c* C	T′	AR.	Δ T.
			h. m. s.	*s.*	*s.*	*s.*	*h. m. s.*	*h. m. s.*	*m. s.*
ε	Pegasi	E.	21 33 50.76	— 0.57	— 0.07	— 0.75	21 33 49.37	21 37 53.23	+ 4 03.86
π	Aquarii		22 14 41.04	— 0.51	— 0.09	— 0.74	22 14 39.70	22 18 43.64	03.94
ζ	Pegasi		31 01.65	— 0.66	— 0.07	— 0.75	31 00.17	35 03.99	03.82
ι	Cephei		41 08.34	— 1.66	+ 0.36	— 1.79	41 05.25	45 09.12	03.87
θ	Piscium	W.	23 17 24.31	— 0.94	— 0.08	+ 0.74	23 17 24.03	23 21 27.82	03.79
ι	Piscium		29 17.88	— 1.02	— 0.08	+ 0.75	29 17.53	33 21.38	+ 4 03.85
	Mean for 22^h 30^m local sidereal time								+ 4 03.855

Normal equations.

$0 = -0.30 + 6.00\,\delta t + 0.28\,a \qquad \delta t = +0^s.055$

$0 = +1.03 + 0.23\,\delta t + 6.57\,a \qquad a = -0^s.158$

Error of collimation found by preliminary reduction $= -0^s.74$.

St. George, Utah, September 14, 1871.

	Name of star.	Clamp.	T	*b* B	*a* A	*c* C	T′	AR.	Δ T
			h. m. s.	*s.*	*s.*	*s.*	*h. m. s.*	*h. m. s.*	*m. s.*
ξ	Aquarii	W.	21 26 42.34	— 0.03	+ 0.64	— 1.46	21 26 41.49	21 30 55.26	+ 4 13.77
ε	Pegasi		33 40.54	+ 0.09	+ 0.42	— 1.46	33 39.59	37 53.23	13.64
μ	Capricorni		42 05.11	— 0.06	+ 0.71	— 1.46	42 04.30	46 18.05	13.75
α	Aquarii		54 58.92	0.00	+ 0.55	— 1.44	54 58.03	59 11.74	13.71
π	Aquarii		22 14 30.82	— 0.10	+ 0.52	— 1.44	22 14 29.80	22 18 43.64	13.84
226	Cephei		26 00.90	— 1.28	— 2.23	— 5.79	25 51.60	30 05.00	13.40
ζ	Pegasi	E.	30 49.11	— 0.24	+ 0.41	+ 1.46	30 50.74	35 03.98	13.24
ι	Cephei		40 54.56	— 0.79	— 2.03	+ 3.48	40 55.22	45 09.11	13.89
α	Pegasi		54 07.67	— 0.29	+ 0.35	+ 1.49	54 09.22	58 22.53	13.31
θ	Piscium		23 17 12.90	— 0.50	+ 0.46	+ 1.45	23 17 14.31	23 21 27.82	+ 4 13.51
	Mean for 22^h 25^m local sidereal time								+ 4 13.606

Normal equations.

$0 = +4.31 + 10.00\,\delta t - 0.23\,a - 3.57\,c$

$0 = -16.67 - 0.23\,\delta t + 14.34\,a + 2.78\,c \qquad a = +0^s.884$

$0 = -45.50 - 3.57\,\delta t + 2.78\,a + 30.07\,c \qquad c = +1^s.444$

St. George, Utah, September 15, 1871.

	Name of star.	Clamp.	T	*b* B	*a* A	*c* C	T′	AR.	Δ T
			h. m. s.	*s.*	*s.*	*s.*	*h. m. s.*	*h. m. s.*	*m. s.*
δ	Ursæ Minoris	E.	18 10 06.18	+4.18	−33.93	−5.46	18 09 30.97	18 13 53.94	+ 4 22.97
α	Lyræ		28 12.63	+0.38	— 0.08	−0.42	28 12.51	32 35.43	22.92
ζ	Aquilæ		55 06.36	+0.26	+ 1.08	−0.33	55 07.37	59 30.29	22.92
τ	Draconis	W.	19 13 43.67	+0.26	— 5.37	+1.12	19 13 39.68	19 18 02.62	22.94
κ	Aquilæ		25 33.83	+0.10	+ 1.32	+0.33	25 35.58	29 58.83	23.25
γ	Aquilæ		35 44.76	+0.14	+ 1.22	+0.33	35 46.45	40 09.32	22.87
α	Aquilæ		40 06.46	+0.17	+ 1.24	+0.33	40 08.20	44 31.11	+ 4 22.91
	Mean for 19^h 0^m local sidereal time								+ 4 22.97

Normal equations.

$0 = +38.84 + 7.00\,\delta t - 13.04\,a + 12.69\,c \qquad \delta t = -0^s.030$

$0 = -516.71 - 13.04\,\delta t + 169.32\,a - 210.22\,c \qquad a = +2^s.647$

$0 = +654.68 + 12.69\,\delta t - 210.22\,a + 301.96\,c \qquad c = -0^s.324$

St. George, Utah, September 15, 1871.

Name of star.	Clamp.	T	*b* B	*a* A	*c* C	T′	AR.	ΔT
		h. m. s.	*s.*	*s.*	*s.*	*h. m. s.*	*h. m. s.*	*m. s.*
β Aquarii	W.	21 20 21.48	−0.20	+1.53	+0.38	21 20 23.19	21 24 48.25	− 4 25.06
ξ Aquarii		26 28.60	−0.06	+2.15	+0.38	26 31.07	30 55.25	24.18
α Aquarii		54 45.11	−0.13	+1.85	+0.38	54 47.21	59 11.74	24.53
π Aquarii		22 14 17.20	−0.24	+1.76	+0.38	22 14 19.10	22 18 43.63	24.53
α Pegasi		53 56.92	−0.38	+1.19	+0.39	53 58.12	58 22.52	24.40
θ Piscium		23 17 01.49	−0.31	+1.56	+0.38	23 17 03.12	23 21 27.82	24.70
γ Cephei		29 53.33	−1.50	−7.86	+1.66	29 45.63	34 10.25	24.62
Groom. 4163	E.	44 23.63	−1.32	−6.34	−1.34	44 14.63	48 40.14	25.51
α Andromedæ		57 21.36	−0.43	+0.54	−0.42	57 21.05	0 01 45.88	24.83
γ Pegasi		70 02 13.10	−0.37	+1.23	−0.39	0 02 13.57	06 38.08	24.51
α Cassiopeæ		28 53.74	−0.80	−1.70	−0.67	28 50.57	33 15.31	24.74
21 Cassiopeæ		33 02.86	−2.67	−6.67	−1.38	32 52.14	37 15.71	+ 4 23.57
Mean for 23h 5m local sidereal time								+ 4 24.60

Normal equations.

$$0 = +33.83 + 12.00\,\delta t - 3.60\,a + 0.72\,c \qquad \delta t = -1^s.900$$
$$0 = -66.22 - 3.60\,\delta t + 18.84\,a - 7.91\,c \qquad a = +2^s.992$$
$$0 = +46.58 + 0.72\,\delta t - 7.91\,a + 57.38\,c \qquad c = -0^s.375$$

The following table contains correction and rate of Hutton 288:

Date.	Hutton's time.	Correction of Hutton.	Rate per hour.
	h.	*h. m. s.*	*s.*
September 13, 1871	8.8492	+11 38 37.134	−10.2265
September 14, 1871	9.0038	42 37.458	−10.4379
September 15, 1871	8.7807	46 35.018	−10.0937

The corresponding observations at Saint George give for Negus 1344:

Date.	Local sidereal time.	Correction of Negus 1344.	Rate per hour adopted.
	h.	*h. m. s.*	*s.*
September 13, 1871	21.1	+0 4 3.122	−0.418
September 14, 1871	22.4	13.606	−0.432
September 15, 1871	21.0	23.785	−0.459

Exchange of signals between Salt Lake City and Saint George.

SEPTEMBER 13, 1871.

Signals sent from Salt Lake City.

Salt Lake chronometer.	Saint George chronometer.	Salt Lake chronometer.	Saint George chronometer.	Salt Lake chronometer.	Saint George chronometer.
h. m. s.	*h. m. s.*	*h. m. s.*	*h. m. s.*	*h. m. s.*	*h. m. s.*
9 11 0.0	20 38 52.7	9 13 10.0	20 41 3.0	9 15 20.0	20 43 13.2
10.0	39 2.8	20.0	13.1	30.0	23.2
20.0	12.6	30.0	23.2	40.0	33.2
30.0	22.6	40.0	33.0	50.0	43.1
40.0	32.6	50.0	43.0	16 0.0	53.2
50.0	42.7	14 0.0	53.2		
12 0.0	52.8			Mean, 9 13 30.00	20 41 23.00
		15 0.0	42 53.4		
13 0.0	40 52.9	10.0	43 3.4		

SEPTEMBER 13, 1871.

Signals sent from Salt Lake City—Continued.

SECOND SERIES.

Salt Lake chronometer.			Saint George chronometer.			Salt Lake chronometer.			Saint George chronometer.			Salt Lake chronometer.			Saint George chronometer.		
h.	m.	s.	h.	m.	s.	h.	m.	s.	h.	m.	s.		h.	m.	s.	h.	m.	s.
9	26	4.2	20	53	59.9	9	28	14.0	20	56	9.6		9	30	26.0	20	58	21.3
		13.8		54	8.8			25.3			20.6				35.7			31.5
		25.1			20.1			35.2			30.5				45.6			41.3
		35.2			30.1			45.7			40.9				55.4			51.0
		45.1			40.2			....			....			31	5.6		59	1.1
		55.1			50.1		29	5.1		57	0.7	Mean,	9	28	29.35	20	56	24.70
	27	4.7			59.9													
							30	....		58	.. .							
	28	5.2		56	0.6			15.6			11.2							

Signals sent from Saint George.

Salt Lake chronometer.			Saint George chronometer.			Salt Lake chronometer.			Saint George chronometer.			Salt Lake chronometer.			Saint George chronometer.		
h.	m.	s.	h.	m.	s.	h.	m.	s.	h.	m.	s.		h.	m.	s.	h.	m.	s.
9	19	6.3	20	47	0.0	9	21	15.8	20	49	10.0		9	23	25.4	20	51	20.0
		16.1			10.0			25.8			20.0				35.4			30.0
		26.2			20.0			35.7			30.0				45.4			40.0
		36.0			30.0			45.6			40.0				55.3			50.0
		46.1			40.0			55.5			50.0			24	5.2		52	0.0
		56.0			50.0		22	5.5		50	0.0							
	20	6.0		48	0.0							Mean,	9	21	35.72	20	49	30.00
							23	5.4		51	0.0							
	21	5.9		49	0.0			15.5			10.0							

SECOND SERIES.

Salt Lake chronometer.			Saint George chronometer.			Salt Lake chronometer.			Saint George chronometer.			Salt Lake chronometer.			Saint George chronometer.		
h.	m.	s.	h.	m.	s.	h.	m.	s.	h.	m.	s.		h.	m.	s.	h.	m.	s.
9	36	44.1	21	4	40.2	9	38	54.1	21	6	51.0		9	41	4.0	21	9	1.3
		53.7			50.3		39	3.6		7	0.6				14.8			12.0
	37	3.6		5	0.2			14.6			11.1				24.6			21.9
		14.2			10.7			24.2			21.0				34.5			31.9
		24.1			20.7			34.0			31.0				44.2			41.7
		34.0			30.4			44.0			41.1							
		43.9			40.5							Mean,	9	39	14.12	21	7	11.02
							40	44.2		8	41.4							
	38	43.8		6	40.9			54.4			51.5							

SEPTEMBER 14, 1871.

Signals sent from Salt Lake City.

Salt Lake chronometer.			Saint George chronometer.			Salt Lake chronometer.			Saint George chronometer.			Salt Lake chronometer.			Saint George chronometer.		
h.	m.	s.	h.	m.	s.	h.	m.	s.	h.	m.	s.		h.	m.	s.	h.	m.	s.
9	.6	0?00	20	37	41.1	9	8	10.0	20	39	51.5		9	10	20.0	20	42	1.8
		10.0			51.1			20.0		40	1.5				30.0			11.8
		20.0		38	1.2			30.0			11.5				40.0			21.8
		30.0			11.2			40.0			21.6				50.0			31.9
		40.0			21.3			50.0			31.5			11	0.0			42.0
		50.0			31.1		9	0.0			41.7							
	7	0.0			41.3							Mean,	9	8	30.00	20	40	11.53
							10	0.0		41	41.8							
	8	0.0		39	41.4			10.0			52.0							

SEPTEMBER 14, 1871.

Signals sent from Salt Lake City—Continued.

SECOND SERIES.

Salt Lake chronometer.			Saint George chronometer.			Salt Lake chronometer.			Saint George chronometer.			Salt Lake chronometer.			Saint George chronometer.		
h.	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*		*h.*	*m.*	*s.*	*h.*	*m.*	*s.*
9	18	46.8	20	50	29.8	9	20	57.1	20	52	40.5		9	23	7.1	20	54	51.0
		57.0			40.0		21	16.9			50.4				17.3		55	1.1
	19	6.7			49.9			17.0		53	0.5				26.4			10.4
		16.6		51	0.0			26.1			9.6				37.6			21.4
		26.0			9.1			37.0			20.5				47.7			31.4
		37.6			20.5			47.5			30.7							
		47.2			30.4							Mean,	9	21	17.33	20	53	0.46
							22	47.4		54	30.9							
	20	47.2		52	39.4			57.5			41.1							

Signals sent from Saint George.

Salt Lake chronometer.			Saint George chronometer.			Salt Lake chronometer.			Saint George chronometer.			Salt Lake chronometer.			Saint George chronometer.		
h.	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*		*h.*	*m.*	*s.*	*h.*	*m.*	*s.*
9	12	18.2	20	44	0.3	9	14	27.5	20	46	10.0		9	16	37.1	20	48	20.0
		27.9			10.0			37.6			20.0				47.1			30.0
		37.8			20.0			47.5			30.0				57.1			40.0
		47.7			30.0			57.6			40.0			17	7.0			50.0
		57.7			40.0		15	7.5			50.0				17.1		49	0.0
	13	7.6			50.0			17.5		47	0.0							
		17.6		45	0.0							Mean,	9	14	47.48	20	46	30.00
							16	17.2		48	0.0							
	14	17.6		46	0.0			27.2			10.0							

SECOND SERIES.

Salt Lake chronometer.			Saint George chronometer.			Salt Lake chronometer.			Saint George chronometer.			Salt Lake chronometer.			Saint George chronometer.		
h.	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*		*h.*	*m.*	*s.*	*h.*	*m.*	*s.*
9	25	36.6	20	57	20.5	9	27	46.0	20	59	30.6		9	29	56.5	21	1	41.4
		45.7			30.0			55.9			40.5			30	7.7			52.3
		55.7			40.1		28	7.1			51.6				16.7		2	1.7
	26	7.1			51.3			16.8	21	0	1.6				27.6			12.6
		16.2		58	0.6			27.1			11.7				37.2			22.2
		27.6			11.7			37.1			21.7							
		37.0			21.4							Mean,	9	28	6.79	20	59	51.36
							29	37.2		1	22.0							
	27	37.2		59	21.7			46.6			31.8							

SEPTEMBER 15, 1871.

Signals sent from Salt Lake City.

Salt Lake chronometer.			St. George chronometer.			Salt Lake chronometer.			St. George chronometer.			Salt Lake chronometer.			St. George chronometer.		
h.	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*		*h.*	*m.*	*s.*	*h.*	*m.*	*s.*
8	53	0.0	20	28	27.5	8	55	10.0	20	30	37.6		8	57	20.0	20	32	48.1
		10.0			37.4			20.0			47.7				30.0			58.1
		20.0			47.3			30.0			57.6				40.0		33	8.0
		30.0			57.4			40.0		31	7.7				50.0			18.0
		40.0		29	7.5			50.0			17.7			58	0.0			28.0
		50.0			17.5		56	0.0			27.8							
	54	0.0			27.5							Mean,	8	55	30.00	20	30	57.76
							57	0.0		32	28.0							
	55	0.0		30	27.5			10.0			38.1							

SEPTEMBER 15, 1871.

Signals sent from Salt Lake City—Continued.

Salt Lake chronometer.	St. George chronometer.	Salt Lake chronometer.	St. George chronometer.	Salt Lake chronometer.	St. George chronometer.
h. m. s.	h. m. s.	h. m. s.	h. m. s.	h. m. s.	h. m. s.
9 8	22 44	9 10 47.6	22 46 17.7	9 12 57.2	22 48 27.6
47.5	17.1	57.4	27.5	13 6.7	37.4
57.5	27.2	11 6.6	36.9	17 9	46.4
9 6.6	36.8	18.3	46.3	27.6	58.4
18.0	48.0	27.4	57.6	38.0	49 8.5
28.1	58.1	37.6	47 8.0		
37.7	45 7.8		18 37.5	Mean, 9 11 15.00	22 46 45.23
		12 37.5	48 8.2		
10 37.6	46 7.8	47.1	17.3		

SEPTEMBER 15, 1871.

Signals sent from St. George.

Salt Lake chronometer.	St. George chronometer.	Salt Lake chronometer.	St. George chronometer.	Salt Lake chronometer.	St. George chronometer.
h. m. s.	h. m. s.	h. m. s.	h. m. s.	h. m. s.	h. m. s.
9 2 31.2	20 38 0.0	9 4 40.7	20 40 10.0	9 6 50.4	20 42 20 0
41.1	10.0	50.8	20.0	7 0.4	30.0
51.2	20.0	5 0.6	30.0	10.5	40.0
3 1.2	30.0	10.6	40.0	20.4	50.0
11.0	40.0	20.6	50.0	30.4	43 0.0
21.1	50.0	30.6	41 0.0		
31.0	39 0.0			Mean, 9 5 0.75	20 40 30.00
		6 30.5	42 0.0		
4 30.9	20 40 0.0	40.6	10.0		

Salt Lake chronometer.	St. George chronometer.	Salt Lake chronometer.	St. George chronometer.	Salt Lake chronometer.	St. George chronometer.
h. m. s.	h. m. s.	h. m. s.	h. m. s.	h. m. s.	h. m. s.
9 14	20 50	9 16 41.6	20 52 12.9	9 18 52.4	20 54 23.6
41.4	12.0	51.6	22.4	19 3.1	34.2
51.3	22.0	17 2.1	33.1	12.6	44.1
15 1.8	32.6	12.0	43.2	22.8	54.2
11.6	42.5	22.1	53.3	32.7	55 4.2
21.7	52.6	32.4	53 3.6		
32.4	51 3.2			Mean, 9 17 9.62	20 52 40.71
		18 32.7	54 4.0		
16 32.3	52 3.3	41.9	13.3		

Signals sent from—	Recorded at—	Mean of signals sent and received.	Time corrections.	Corrected time.	Difference of longitude.	Means.
September 13, 1871.						
		h. m. s.	h. m. s.	h. m. s.	h. m. s.	h. m. s.
Salt Lake	St. George	9 13 30.00	+11 38 40.98	20 52 10.98		
		20 41 23.00	+ 0 4 2.95	20 45 25.95	0 6 45.03	
		9 28 29.35	+11 38 43.53	21 7 12.88		
		20 56 24.70	+ 0 4 3.05	21 0 27.75	45.13	
St. George	Salt Lake	9 21 35.72	+11 38 42.36	21 0 18.08		
		20 49 30.00	+ 0 4 3.01	20 53 33.01	45.07	
		9 39 14.12	+11 38 45.36	21 17 59.48		
		21 7 11.02	+ 0 4 3.13	21 11 14.15	45.33	0 6 45.14

Signals sent from—	Recorded at—	Mean of signals sent and received.	Time corrections.	Corrected time.	Difference of longitude.	Means.
September 14, 1871.		h. m. s.	h. m. s.	h. m. s.	h. m. s.	h. m. s
Salt Lake	St. George	9 8 30.00	+11 42 38.90	20 51 8.90		
		20 40 11.53	+ 0 4 12.88	20 44 24.41	44.49	
		9 21 17.33	+11 42 41.12	21 3 58.45		
		20 53 0.46	+ 0 4 12.98	20 57 13.44	45.01	
St. George	Salt Lake	9 14 47.48	+11 42 39.99	20 57 27.47		
		20 46 30.00	+ 0 4 12.93	20 50 42.93	44.54	
		9 28 6.79	+11 42 42.31	21 10 49.10		
		20 59 51.38	+ 0 4 13.03	21 4 4.41	44.69	44.68
September 15, 1871.						
Salt Lake	St. George	8 55 30.00	+11 46 36.48	20 42 6.48		
		20 30 57.76	+ 0 4 23.60	20 35 21.36	45.12	
		9 11 15.00	+11 46 39.12	20 57 54.12		
		22 46 45.23	+ 0 4 23.72	20 51 8.95	45.17	
St. George	Salt Lake	9 5 0.75	+11 46 38.07	20 51 38.82		
		20 40 30.00	+ 0 4 23.67	20 44 53.67	45.15	
		9 17 9.62	+11 46 40.12	21 3 49.74		
		20 52 40.71	+ 0 4 23.76	20 57 4.47	45.27	45.18

	h. m. s.
Final difference of longitude, St. George, west of Salt Lake	0 6 45.08
Adopted longitude, (by excluding September 14, 1871)	0 6 45.16

Mean places of stars for 1871.0, *used for determination of latitude of St. George, Utah.*

No. in B. A. C.	Declination.	No. in B. A. C.	Declination.	No. in B. A. C.	Declination.	No. in B. A. C.	Declination.
	° ′ ″		° ′ ″		° ′ ″		° ′ ″
6404	41 18 15.82	6731	44 24 40.50	7029	31 46 30.12	7474	23 4 28.25
6426	32 39 56.12	6740	29 51 26.07	7041	42 11 1.46	7512	51 7 27.61
6473	41 26 19.86	6784	33 25 42.66	7121	14 8 52.88	7548	49 5 53.46
6491	32 30 50.60	6817	40 16 22.12	7160	14 7 31.14	7571	25 3 10.73
				7176	60 2 22.18		
6542	24 3 8.51	6839	16 17 41.03	7193	60 8 14.29	7598	48 42 47.58
6566	50 9 24.24	6863	57 54 36.98			7627	25 19 8.54
				7218	52 31 33.82		
6589	21 9 50.63	6882	24 26 37.77	7275	21 49 41.53	7736	58 39 42.29
6623	53 7 52.68	6895	49 44 47.56			7742	15 24 20.81
				7317	44 16 58.50	7755	58 46 41.68
6659	50 1 11.62	6912	23 14 38.59	7368	29 41 56.66		
6674	24 24 19.93	6959	51 4 35.00			7807	20 11 49.54
				7410	23 18 50.27	7846	53 35 9.44
6712	58 19 28.10	6986	39 58 0.90	7448	51 6 11.60		
6724	16 10 29.08	6998	34 34 51.16				

Observations for latitude.—Station, Saint George, Utah.

Date.	No. of star.	Micrometer-readings.	Level. N.	Level. S.	Remarks.
1871.					
Sept. 19	6404	25 72.9	8.9	8.4	
	6426	15 20.0	9.0	8.5	
	6473	19 78.5	8.0	9.5	
	6491	8 46.8	9.5	8.3	
	6542	17 81.9	8.4	9.7	
	6566	17 70.9	10.1	8.0	
	6589	22 45.8	9.0	9.1	
	6623	18 49.9	9.1	9.0	
	6639	20 60.0	7.7	10.9	
	6863	20 72.3	11.0	7.5	
	6882	20 34.4	8.0	11.0	
	6895	21 4.5	10.0	8.5	
20	6404	25 69.9	8.9	8.0	
	6426	15 20.1	9.0	8.0	
	6473	19 70.5	9.4	7.8	
	6491	8 46.8	9.0	8.5	
	6542	17 24.6	9.0	8.5	
	6566	17 4.9	10.0	7.4	
	6659	16 10.0	11.0	6.8	
	6674	25 90.6	8.3	9.1	
	6712	10 40.3	8.9	8.4	
	6784	23 49.1	10.3	7.0	
	6731	18 13.7	6.0	11.4	
	6740	20 90.8	13.1	4.4	
	6784	12 41.2	8.6	9.3	
	6817	34 78.9	9.9	8.0	Must be 87.9
	6839	21 4.0	7.7	10.0	
	6863	21 4.0	13.7	4.0	
	6882	19 45.1	10.0	7.8	
	6895	20 9.5	10.0	7.3	
	6912	21 75.7	9.0	8.5	
	6959	16 63.3	11.2	6.5	
	6986	11 1.0	9.6	8.4	
	6998	26 30.7	10.0	8.7	
	7029	13 13.1	8.8	9.9	
	7041	24 5.0	12.0	6.8	
21	6404	26 14.0	8.3	7.1	
	6426	15 59.7	7.5	8.1	
	6473	20 14.5	9.0	6.8	
	6491	8 86.0	7.4	8.7	
	6542	17 48.0	8.5	8.0	
	6566	17 35.1	8.8	8.0	
	6589	22 41.6	7.0	10.2	
	6623	18 43.2	10.5	6.6	
	6659	15 97.8	11.1	6.3	
	6674	25 74.0	6.5	11.2	
	6712	10 1.3	8.0	9.7	
	6724	23 3.0	10.0	8.0	
	6731	18 13.5	9.7	8.4	
	6740	20 93.0	9.5	8.8	
1871.					
Sept. 21	6839	21 6.7	9.6	9.4	
	6863	21 14.1	9.8	9.0	
	6882	19 16.0	8.6	10.4	
	6895	19 77.1	12.0	6.8	
	6912	22 49.4	5.0	13.9	
	6959	17 34.7	15.3	3.4	
	6986	11 14.0	12.1	6.3	
	6998	26 39.7	7.2	11.3	
	7029	12 52.8	7.7	11.0	
	7041	23 49.7	10.0	7.7	
22	6404	25 33.5	8.8	7.9	
	6426	15 41.3	7.3	9.3	
	6473	20 10.4	5.5	11.5	
	6491	8 68.5	8.5	8.9	
	6542	17 56.1	7.9	9.8	
	6566	17 43.0	10.0	7.3	
	6589	23 5.9	9.0	8.7	
	6623	19 9.6	9.1	8.4	
	6659	16 6.4	11.0	6.9	
	6674	26 1.3	12.0	6.0	
	6712	10 26.7	9.0	9.0	
	6724	23 33.3	9.0	9.0	
	6784	12 35.3	8.7	10.4	
	6817	34 90.9	6.1	12.0	
	6839	21 10.0	11.9	8.8	
	6863	21 16.4	7.6	11.9	
	6882	19 30.0	9.4	10.4	
	6895	20 7.8	7.9	12.0	
	6912	22 50.7	9.9	10.3	
	6959	17 42.1	10.5	10.0	
	6986	11 27.4	10.8	9.9	
	6998	26 48.0	9.2	11.2	
	7029	12 85.6	5.5	15.0	
	7041	23 83.2	15.0	5.5	
	7121	22 24.8	10.6	10.5	
	7160	21 24.3	10.8	10.6	
	7176	23 8.0	10.3	10.5	
	7193	18 73.9	10.2	10.5	
	7218	16 16.8	11.0	10.0	
	7275	22 78.4	10.0	101	
	7410	29 10.8	11.0	10.0	
	7448	19 73.0	9.9	11.1	
	7474	18 46.3	11.3	10.0	
	7512	18 81.4	10.6	11.3	
	7548	19 76.5	11.7	9.4	
	7571	17 34.3	9.4	11.9	
	7598	22 86.2	11.4	10.0	
	7627	15 14.6	9.5	12.2	
	7736	25 0.1	12.1	10.0	
	7742	18 77.9	9.4	13.1	
	7755	19 76.3	12.3	9.0	

Observations for latitude.—Station, Saint George, Utah—Continued.

Date.	No. of star.	Micrometer-readings.	Level. N.	Level. S.	Remarks.
1871.					
Sept. 22	7807	9 40.7	12.0	11.0	
	7846	28 25.7	11.8	11.8	
23	6404	26 16.1	9.6	8.5	
	6426	15 70.2	10.3	7.7	
	6473	20 16.9	9.7	8.5	
	6491	8 92.5	10.0	8.2	
	6542	17 82.9	9.8	8.9	
	6566	17 65.4	10.3	8.3	
	6589	22 52.3	8.6	10.5	
	6623	18 47.1	13.1	5.8	
	6659	16 39.9	10.9	8.5	
	6674	26 20.8	10.0	9.5	
	6712	10 57.9	8.0	11.4	
	6724	23 65.6	12.9	6.9	
	6839	21 8.6	9.0	10.3	
	6863	21 8.2	13.3	6.4	
	6882	19 59.0	9.4	10.1	
	6895	20 22.5	12.1	7.4	
	6912	22 73.9	14.0	5.6	
	6959	17 59.3	8.1	12.0	
	6986	11 34.9	9.8	10.5	
	6998	26 60.3	13.3	7.0	
	7029	12 94.1	11.5	9.1	
	7041	23 68.0	16.4	4.1	
	7121	22 31.0	11.0	10.6	
	7160	21 28.9	11.0	10.7	
	7176	23 4.0	13.5	7.5	
	7193	18 70.1	13.4	7.5	
	7218	16 14.4	11.1	11.1	
	7275	22 76.3	11.4	11.6	
	7317	26 95.0	11.0	11.5	
	7368	16 96.4	10.6	11.9	
	7410	29 50.2	10.7	11.9	
	7448	20 14.0	11.1	11.0	
	7474	18 87.5	11.1	11.0	
	7512	19 13.7	13.8	8.5	
	7548	20 52.2	12.0	10.3	
	7571	18 15.6	12.9	9.5	
	7598	22 34.1	11.0	11.4	
	7627	14 70.4	14.5	8.1	
	7807	9 28.8	12.6	10.0	
	7846	8 4.7	12.0	10.6	
24	6659	16 46.2	5.0	13.4	
	6674	26 9.3	10.0	8.9	
	6731	17 70.0	10.4	8.5	
	6740	20 45.4	8.5	10.4	
	6784	8 62.0	9.0	10.0	
	6817	31 3.4	9.9	9.5	
	6882	19 50.5	8.6	11.0	
	6895	20 18.2	11.6	7.9	

Date.	No. of star.	Micrometer-readings.	Level. N.	Level. S.	Remarks.
1871.					
Sept. 24	7029	13 2.6	10.7	9.9	
	7041	23 98.3	10.4	10.2	
	2121	22 24.3	10.1	11.0	
	7160	21 27.5	11.1	10.1	
	7176	23 10.8	10.0	11.2	
	7193	18 74.9	10.0	11.1	
	7218	15 85.7	10.9	10.6	
	7275	22 49.9	11.2	10.6	
	7217	27 2.0	3.6	13.5	Very faint.
	7368	16 97.0	9.7	12.3	
	7410	29 13.4	11.9	10.3	
	7448	19 72.4	11.1	11.1	
	7474	23 52.5	12.4	9.9	
	7512	23 78.9	12.0	10.2	
	7548	19 74.3	15.1	6.6	
	7571	17 31.4	7.0	14.5	
	7598	22 66.3	9.0	12.5	
	7627	14 80.6	8.3	13.2	
	7736	25 8.9	7.8	14.1	
	7742	18 99.0	16.8	5.1	
	7755	19 77.4	11.0	10.9	
	7807	9 11.1	10.9	10.5	
	7846	28 1.3	9.0	12.4	
25	6404	26 22.0	7.7	9.3	
	6426	15 69.8	9.0	8.0	
	6473	20 28.4	8.6	9.0	
	6491	8 96.7	9.0	8.6	
	6731	17 13.5	13.7	5.0	
	6740	20 4.4	9.5	9.3	
	6784	8 65.9	8.0	10.5	
	6817	31 8.5	11.1	7.6	
	6882	19 53.7	10.0	9.6	
	6895	20 24.0	9.0	10.5	
	7029	13 25.6	11.6	8.8	
	7041	24 23.1	7.5	13.0	
	7121	21 88.9	8.8	10.0	
	7160	20 88.6	9.0	9.9	
	7176	22 71.1	10.6	8.1	
	7193	18 36.4	10.4	8.4	
	7218	16 13.1	9.3	11.8	
	7275	22 64.5	9.5	12.0	
	7410	28 69.4	10.5	11.6	
	7448	19 27.7	12.0	9.8	
	7474	18 1.7	10.0	12.1	
	7512	18 33.6	12.4	9.7	
	7598	22 65.0	11.9	10.5	
	7627	14 83.1	7.5	14.9	
	7736	25 3.9	13.0	9.9	
	7742	18 86.7	9.8	13.2	
	7755	19 80.8	14.0	9.0	
	7807	9 20.0	12.3	11.0	
	7846	27 98.0	11.8	11.6	

Computations for latitude of St. George, Utah.

Mean latitude of St. George, Utah: 37° 6′ 29″.38 ± 0″.08.

Date.	No. of pair.	Half-sum of declination.	Corrections.			Latitude.
			Micr. and refr.	Level.	Merid.	
		° ′ ″	′ ″	″		° ′ ″
September 19, 1871	1	36 59 23.58	+ 7 5.81	+ 0.67	.....	37 6 30.06
	2	58 52.98	+ 7 37.68	− 0.14	.....	30.52
	3	37 6 33.93	− 0 4.45	+ 0.54	.....	30.02
	4	9 9.16	− 2 40.11	0.00	.....	29.05
	6	15 15.90	− 8 47.94	− 0.07	.....	27.89
	9	6 26.50	+ 0 4.97	+ 0.20	.....	31.67
	10	6 0.87	+ 0 28.34	− 1.01	.....	28.20
September 20, 1871	1	36 59 23.61	+ 7 4.55	+ 1.27	.....	29.43
	2	58 53.04	+ 7 34.44	+ 1.41	.....	28.89
	3	37 6 34.00	− 0 7.96	+ 2.09	.....	28.13
	5	13 3.77	− 6 36.57	+ 2.29	.....	29.49
	6	15 15.99	− 8 49.31	+ 2.57	.....	29.25
	7	8 21.69	− 1 52.07	+ 2.56	.....	32.18
	8	36 51 20.96	+15 8.61	+ 0.80	.....	30.37
	9	37 6 26.62	+ 0 0.00	+ 5.00	.....	31.62
	10	6 1.00	+ 0 26.04	+ 3.31	.....	30.35
	11	9 55.07	− 3 27.23	+ 3.51	.....	31.35
	12	16 44.84	−10 18.63	+ 1.69	.....	27.90
	13	36 59 4.51	+ 7 21.59	+ 2.77	.....	28.87
September 21, 1871	1	36 59 23.65	+ 7 6.37	+ 0.40	.....	30.42
	3	37 6 34.07	− 0 51.22	+ 0.88	.....	29.73
	4	9 9.31	− 2 41.12	+ 0.47	.....	28.66
	5	13 3.84	− 6 34.79	+ 0.07	.....	29.12
	6	15 16.08	− 8 46.44	+ 0.20	.....	29.84
	7	8 21.78	− 1 53.04	+ 1.35	.....	30.09
	9	6 26.73	+ 0 2.99	+ 0.67	.....	30.39
	10	6 1.12	+ 0 24.70	+ 2.30	.....	28.12
	11	9 55.20	− 3 28.16	+ 2.02	.....	29.06
	12	16 44.97	−10 17.01	+ 1.15	.....	29.11
	13	36 59 4.65	+ 7 23.61	0.00	.....	28.26
September 22, 1871	1	36 59 23.69	+ 7 5.52	− 0.74	.....	28.47
	2	58 53.15	+ 7 41.80	+ 4.32	.....	30.63
	3	37 6 34.13	− 0 5.30	+ 0.54	.....	29.37
	4	9 9.38	− 2 41.08	+ 0.68	.....	28.98
	5	13 3.92	− 6 42.35	+ 6.82	.....	28.39
	6	15 16.16	− 8 48.42	0.00	.....	27.74
	8	36 51 21.17	+15 12.21	− 5.13	.....	26.25
	9	37 6 26.84	+ 0 2.39	− 0.81	.....	28.62
	10	6 1.23	+ 0 31.45	− 3.44	.....	29.24
	11	9 55.32	− 3 25.70	+ 0.07	.....	29.69
	12	16 45.10	−10 14.95	− 0.74	.....	29.41
	13	36 59 4.78	+ 7 23.89	0.00	.....	28.67
	14	37 5 55.35	+ 0 33.65	− 0.07	.....	28.93
	15	8 10.55	− 1 41.27	− 0.07	.....	29.21
	16	10 56.26	− 4 27.57	+ 0.61	.....	29.30
	18	12 49.32	− 6 19.26	− 0.14	.....	29.92
	19	6 16.09	+ 0 14.19	0.00	.....	30.28
	20	4 50.35	+ 1 17.95	− 0.13	.....	28.17
	21	1 16.23	+ 5 12.06	− 0.88	.....	27.41
	22	2 18.68	+ 4 11.64	− 1.08	.....	29.24
	23	5 48.36	+ 0 39.79	− 0.94	.....	27.21
	24	36 53 46.64	+12 42.34	+ 0.67	.....	29.74
September 23, 1871	1	36 59 23.72	+ 7 2.98	+ 2.50	.....	29.20
	2	58 53.20	+ 7 34.72	+ 2.02	.....	29.94
	3	37 6 34.18	− 0 7.08	+ 1.96	.....	29.06
	4	9 9.45	− 2 43.87	+ 3.78	.....	29.36
	5	13 4.00	− 6 36.69	+ 1.96	.....	29.27
	6	15 16.25	− 8 48.86	+ 1.76	.....	29.15
	9	6 26.94	+ 0 0.08	+ 3.78	.....	30.80
	10	6 1.35	+ 0 25.67	+ 2.70	.....	29.72
	11	9 55.45	− 3 28.12	+ 3.04	.....	30.37
	12	16 45.23	−10 16.89	+ 3.78	.....	32.12
	13	36 59 4.92	+ 7 14.31	+ 9.92	.....	29.15
	14	37 5 55.49	+ 0 29.22	+ 4.32	.....	29.33
	15	8 10.69	− 1 44.66	+ 4.18	.....	30.21
	16	10 56.41	− 4 27.70	− 0.14	.....	28.57
	17	36 59 46.58	+ 6 43.84	− 1.22	.....	29.20
	18	37 12 49.50	− 6 18.62	− 0.74	.....	30.14
	19	6 16.27	+ 0 10.59	+ 3.64	.....	30.50
	20	4 50.54	+ 1 35.69	+ 3.44	.....	29.57
	21	1 16.42	+ 5 8.86	+ 4.05	.....	29.33
	24	36 53 46.82	+12 38.66	+ 2.70	.....	28.18

Computations for latitude of St. George, Utah—Continued.

Date.	No. of pair.	Half-sum of declination.	Corrections.			Latitude.
			Micr. and refr.	Level.	Merid.	
		° ′ ″	′ ″	″		° ′ ″
September 24, 1871	5	37 13 4.08	− 6 29.49	− 4.93		37 6 29.66
	7	8 22.05	− 1 51.38	0.00		30.67
	8	36 51 21.36	+15 6.47	− 0.40		27.43
	10	37 6 1.45	+ 0 27.30	+ 0.68		29.43
	13	36 59 5.05	+ 7 23.12	+ 0.67		28.84
	14	37 5 55.63	+ 0 34.98	− 1.42		29.19
	15	8 10.83	− 1 42.16	− 0.07		28.60
	16	10 56.56	− 4 28.63	+ 0.61		28.54
	17	36 59 46.73	+ 6 46.43	− 5.06		28.10
	18	37 12 49.67	− 6 20.56	+ 1.08		30.19
	19	6 16.45	− 0 10.67	+ 2.90		30.68
	20	4 50.73	+ 1 38.23	+ 0.67		29.63
	21	1 16.61	+ 5 17.76	− 5.67		29.70
	22	2 19.07	+ 4 6.66	+ 3.64		29.37
	23	5 48.75	+ 0 31.71	+ 7.96		29.42
	24	36 53 47.00	+12 21.44	− 2.02		31.42
September 25, 1871	1	36 59 23.79	+ 7 5.52	− 0.40		28.91
	2	58 53.29	+ 7 37.68	0.00		30.97
	7	37 8 22.14	− 1 57.65	− 6.01		30.50
	8	36 51 21.45	+15 6.95	+ 0.68		29.08
	10	37 6 1.55	+ 0 28.43	− 0.75		29.23
	13	36 59 5.18	+ 7 23.85	− 1.82		27.21
	14	37 5 55.76	+ 0 33.24	+ 0 88		29.88
	15	8 10.97	− 1 41.99	+ 0.74		29.72
	16	10 56.72	− 4 23.45	− 3.37		29.90
	18	12 49.85	− 6 20.84	+ 0.74		29.75
	19	6 16.63	+ 0 12.90	+ 0.40		29.93
	21	1 16.81	+ 5 16.22	− 4.05		29.98
	22	2 19.28	+ 4 9.61	− 0.20		29.69
	23	5 48.95	+ 0 38.05	+ 1.08		29.08
	24	36 53 47.17	+12 39.75	+ 1.01		27.93

Adopting the longitude of Salt Lake, 111° 53′ 42″.90 west of Greenwich, the astronomical co-ordinates of St. George will be:

Longitude, 113° 35′ 0″.30 west of Greenwich.

Longitude, 36° 31′ 58″.50 west of Washington.

Latitude: N. 37° 6′ 29″.38 ± 0″.08.

The results obtained for the longitude by lunar culminations of Camp Independence, California, and Fort Whipple, Arizona Territory, and for the latitude of Camp Independence, California, will be incorporated in the astronomical volume.

In the same publication will appear a list of the geographical positions established by the survey.

Observations and computations for latitude.—Station, Fort Whipple, Arizona Ter.

OCTOBER 27, 1871.

Number of star.	Micrometer readings.	Level.		Remarks.	Half-sum of declination.	Corrections.			Latitude.
		N.	S.			Micrometer and reference.	Level.	Merid.	
	t d.				° ′ ″	′ ″	″		° ′ ″
6990	12 40.4	12.5	13.8						
7029	26 52.2	15.7	11.0	.....	34 42 35.1	− 9 30.5	+2.3	.....	34 33 6.9
7061	16 86.3	11.9	18.2						
7131	19 6.5	19.0	12.0	.....	34 34.6	− 1 29.6	+0.5	.....	6.1
7275	13 76.4	16.3	16.0						
7301	24 67.0	15.0	17.1	.....	25 46.7	+ 7 20.7	−1.2	.....	6.2
7372	17 49.9	17.0	16.0						
7387	19 32.5	16.0	17.2	.....	31 53.5	+ 1 13.8	−0.1	.....	7.2

Observations and computations for latitude of Fort Whipple, Arizona—Continued.

OCTOBER 27, 1871.

Number of star.	Micrometer-readings.	Level. N.	Level. S.	Remarks.	Half sum of declination.	Corrections. Micrometer and reference.	Corrections. Level.	Corrections. Meridian.	Latitude.
	h. d.				° ′ ″	′ ″	″		° ′ ″
7455	14 82.7	20.1	13.6						
7474	21 3.9	12.9	20.8	.....	34 37 18.0	− 4 11.0	−0.9	.....	34 33 6.1
7520	24 70.4	16.4	17.6						
7560	13 58.7	17.7	16.7	.....	40 35.8	− 7 29.2	−0.1	.....	6.5
7606	14 81.4	5.5	5.6						
7676	21 26.5	2.9	7.3	.....	28 48.9	+ 4 20.7	−3.0	.....	6.6
7749	19 32.3	4.9	4.9						
7796	20 65.3	4.0	5.8	.....	34 2.0	− 0 53.7	−1.2	.....	7.1
7807	19 8.6	2.8	4.0						
7820	22 24.8	4.0	3.0	.....	30 58.4	+ 2 7.6	−0.1	.....	5.9
7915	19 70.0	7.5	6.4						
7923	20 4.2	4.9	9.0	.....	33 22.2	− 0 13.8	−2.0	.....	6.4
8023	22 60.7	7.1	7.0						
8032	19 24.2	5.3	8.9	.....	30 52.7	+ 2 16.0	−2.4	.....	6.3
8076	20 60.7	6.7	8.0						
8079	16 59.0	6.5	8.0	.....	30 27.1	+ 2 42.3	−1.9	.....	7.5
8097	15 74.2	8.5	7.4	?					
8128	23 73.4	6.5	8.3	.....	27 53.9	+ 5 10.8	−0.5	.....	4.2
8158	26 10.1	6.1	8.3						
8182	16 50.8	6.8	7.9	.....	26 40.6	+ 6 27.6	−2.2	.....	6.0
8195	19 80.5	7.9	7.0						
8206	22 0.8	5.3	9.1	.....	34 36.1	− 1 29.0	−2.0	.....	5.1
8250	15 42.4	8.0	6.7						
8280	25 1.5	5.1	9.9	.....	26 38.9	+ 6 27.6	−2.4	.....	4.1
8299	20 90.1	7.3	7.9						
8307	15 74.8	6.0	9.1	.....	36 36.8	− 3 28.2	−2.5	.....	6.1
8335	16 59.0	7.1	8.0						
7	21 0.9	8.0	7.1	.....	30 5.3	+ 2 58.6	0.0	.....	3.9
166	16 83.9	8.6	6.0						
173	25 23.6	3.2	10.0	.....	28 28.6	+ 5 39.3	−2.8	.....	5.1
201	14 0.9	6.4	7.6						
211	22 60.1	5.7	8.2	.....	38 55.2	− 5 47.2	−2.5	.....	5.5
232	15 93.0	5.8	8.5						
235	13 11.1	5.9	8.4	.....	39 7.9	− 6 8.0	+7.3	.....	7.2
247	25 3.7	14.0	0.4	.....	41 3.4	− 8 1.9	+4.1	.....	5.6

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	h. d.								
7275	13 63.2	5.1	8.5						
7301	24 47.1	9.9	4.0	.....	25 46.6	+ 7 18.0	+1.7	.....	34 33 6.3
7345	19 48.3	9.6	4.0	.....	29 9.4	+ 3 56.4	+1.5	.....	7.3
				Cloudy.					
8299	20 29.2	8.3	8.7						
8307	15 2.0	9.6	6.3	.....	36 37.0	−2 33.0	+2.0	.....	6.0
48	18 98.8	7.0	9.0						
92	17 45.0	10.9	5.3	.....	34 7.6	−1 2.2	+2.4	.....	7.8
166	16 55.9	18.4	19.6						
173	25 6.0	15.0	22.9	.....	28 28.8	+5 43.5	−6.1	.....	6.2
201	14 77.4	7.8	9.5						
211	23 45.5	11.0	6.4	.....	38 55.3	−5 51.6	+2.0	.....	5.7
232	15 53.3	4.6	12.7						
247	24 48.5	13.0	4.0	.....	39 8.1	−6 1.8	+0.8	.....	7.1

Observations and computations for latitude of Fort Whipple, Arizona—Continued.

OCTOBER 29, 1871.

Number of star.	Micrometer readings.	Level. N.	Level. S.	Remarks.	Half sum of declination.	Corrections. Micrometer and reference.	Corrections. Level.	Corrections. Meridian.	Latitude.
	t. d.				° ′ ″	″	″		° ′ ″
7275	13 12.4	7.7	3.2						
7301	23 99 2	3.3	7.5	.....	34 25 46.6	+7 19.2	+0.2	.....	34 33 6
7345	18 99.6	3.9	7.7	.....	29 9.4	+3 57.3	+0.4	.....	3
7372	16 55.9	6.8	5.0						
7387	18 33.0	5.6	6.3	.....	31 53.5	+1 11.6	−0.7	.....	3
7455	14 50.2	5.3	6.8						
7474	20 79.1	8.4	4.0	.....	37 18.0	−4 14.1	+1.9	.....	3
7520	24 27.4	7.0	5.4						
7560	13 10.0	7.2	5.2	.....	40 35.8	−7 31.5	+2.4	.....	3
7641	16 6.1	6.3	7.0						
7683	27 3.6	9.0	4.6	.....	25 40.4	+7 23.5	+2.5	.....	3
7749	18 72.7	9.1	4.5						
7796	20 13.5	5.5	8.5	.....	34 2.1	−0 56.9	+1.1	.....	3
7807	20 73.0	3.6	10.7						
7820	22 78.0	14.7	− 0.8	.....	30 58.5	+2 3.2	+5.7	.....	3
7915	19 7.0	8.0	7.2						
7923	19 52.4	7.8	6.9	.....	33 22.4	−0 18.4	+1.1	.....	3
7943	25 57.0	6.5	7.8						
7953	15 62.6	7.2	7.2	.....	39 48.5	−6 41.8	−0.9	.....	3
8023	22 67.0	8.5	6.6						
8032	19 40.7	7.3	7.8	.....	30 52.9	+2 11.9	+0.9	.....	3
8076	20 25.8	8.2	7.0						
8079	16 35.4	7.2	8.0	.....	30 27.3	+2 37.7	+0.3	.....	3
8158	25 85.0	5.6	9.5						
8182	16 33.8	10.0	5.2	.....	26 40.8	+6 24.4	+0.6	.....	3
8195	16 51.0	8.1	7.2						
8206	18 82.2	8.5	7.0	.....	34 36.3	−1 33.4	+1.6	.....	3
8250	15 31.3	7.4	8.1						
8280	24 94.0	8.1	7.3	.....	26 39.1	+6 29.0	0.0	.....	3
48	19 14.5	7.6	8.0						
92	17 62.1	7.9	8.2	.....	34 7.7	− 1 1.6	−0.5	.....	3
122	12 48.5	8.5	7.5						
146	26 97.8	7.5	8.7	.....	23 19.7	+ 9 45.6	−0.1	.....	3
201	13 76.2	8.7	7.8						
211	22 40.7	7.8	8.8	.....	38 55.4	− 5 49.3	−0.1	.....	3
232	15 42.3	8.4	8.0						
235	12 58.0	8.2	8.0	.....	39 8.2	− 6 0.7	+0.1	.....	3
247	24 34.9	8.0	8.3	.....	41 3.6	− 7 55.6	−0.1	.....	3

OCTOBER 30, 1871.

7275	12 90.6	7.3	7.0						
7301	23 83.4	5.8	7.4	.....	34 25 46.6	+ 7 21.6	−0.9	.....	34 33
7345	18 78.4	6.2	8.4	.....	29 9.3	+ 3 57.5	−1.3	.....	
7372	16 71.3	6.8	8.0						
7377	23 35.7	7.8	7.0	.....	28 36.4	+ 4 28.5	−0.3	.....	
7455	14 47.3	9.5	5.8						
7474	20 70.6	6.0	9.6	.....	37 18.0	− 4 11.9	− 0.1	.....	
7520	24 44.9	8.0	7.4						
7560	13 39.2	7.3	8.5	.....	40 35.8	− 7 26.8	−0.4	.....	
7641	15 80.1	7.3	8.5						
7683	26 84.0	8.6	7.9	.....	25 40.4	− 7 26.1	−0.3	.....	

Observations and computations for latitude of Fort Whipple, Arizona—Continued.

OCTOBER 30, 1871.

Number of star.	Micrometer readings.	Level. N.	Level. S.	Remarks.	Half sum of declination.	Corrections. Micrometer and reference.	Corrections. Level.	Corrections. Meridian.	Latitude.
	t. d.				° ′ ″	′ ″	″		° ′ ″
7749	18 57.6	6.0	10.3						
7796	19 88.4	7.5	8.9	.....	34 34 2.2	− 0 52.9	−3.8	.....	34 33 5.5
7807	18 95.8	6.7	9.8						
7820	22 0.5	12.5	3.7	.....	30 58.6	+ 2 3.1	+3.9	.....	5.6
7915	18 95.1	8.6	7.7						
7923	19 35.3	7.7	8.6	.....	33 22.5	− 0 16.2	0.0	.....	6.3
7943	25 64.5	8.6	7.5						
7953	15 70.2	7.4	9.0	.....	39 48.6	− 6 41.8	−0.3	.....	6.5
8158	24 41.0	7.8	8.5						
8182	14 82.2	8.0	8.1	.....	26 41.0	+ 6 27.5	−0.5	.....	8.0
8250	15 94.3	8.0	7.8		2				
8280	25 42.6	10.2	6.4	.....	26 39.2	+ 6 23.2	+2.7	.....	5.1
8299	26 22.0	7.9	9.0						
8307	15 11.7	5.6	11.0	.....	36 37.2	− 3 26.2	−4.4	.....	6.6
8335	16 31.0	7.7	9.2						
7	20 74.7	8.6	8.8	.....	30 5.7	+ 2 59.3	−1.1	.....	3.9
48	19 33.9	9.0	8.6						
92	17 83.4	8.7	9.1	.....	34 8.0	− 1 0.08	0.0	.....	7.2
116	13 1.2	8.9	9.1						
122	12 34.3	9.1	9.0	.....	23 47.2	+ 9 17.3	+0.1	.....	4.6
146	26 80.3	9.1	8.8	.....	23 19.8	+ 9 44.3	+0.3	.....	4.4

OCTOBER 31, 1871.

166	16 53.7	9.5	8.5						
173	24 91.4	8.0	10.0	.....	34 27 29.0	+ 5 38.5	−0.7	.....	34 33 6.8
201	13 86.5	9.0	9.0						
211	22 49.3	7.9	10.0	.....	38 55.6	− 5 48.7	−1.4	.....	5.5
232	15 12.1	7.2	10.7						
235	12 29.2	6.6	11.4	.....	39 8.4	− 6 2.9	−3.1	.....	8.6
247	24 10.0	13.1	5.0	.....	41 3.8	− 7 57.2	+2.2	.....	8.8
7204	28 23.0	8.7	4.5						
7213	9 77.6	4.6	8.6	.....	45 32.1	−12 25.7	−0.1	.....	6.5
7275	13 16.7	11.4	10.4						
7301	23 98.4	12.0	9.8	.....	25 46.7	+ 7 17.1	+2.2	.....	6.0
7345	19 9.7	9.0	13.0	.....	29 9.4	− 3 59.6	−2.0	.....	7.0
7372	16 33.5	10.3	12.0						
7387	18 6.4	13.2	9.0	Very faint	31 53.6	+ 1 9.9	+1.7	.....	5.2
7455	14 37.0	11.0	12.0						
7474	20 69.2	14.6	8.5	.....	37 18.1	− 4 15.5	+3.4	.....	6.0
7529	23 98.9	11.0	12.1						
7560	12 82.0	13.0	9.4	.....	40 35.9	− 7 31.3	+1.7	.....	6.3
7606	13 84.1	12.0	11.5						
7676	20 14.7	13.1	11.0	.....	28 49.2	+ 4 14.8	+1.8	.....	5.8
7719	18 16.7	12.0	12.2						
7796	19 49.3	10.0	14.7	.....	34 2.2	− 0 53.6	−3.3	.....	5.3
7897	18 55.2	16.2	8.3						
7820	21 68.0	7.8	12.0	.....	30 58.7	+ 2 6.4	+2.5	.....	7.6
7915	18 89.5	7.7	7.7						
7923	19 28.0	6.8	8.5	.....	33 22.6	− 0 15.6	−1.1	.....	5.9
7943	25 84.9	8.4	6.8						
7953	15 89.0	8.0	7.4	.....	39 48.7	− 6 42.5	+1.5	.....	7.7
8023	22 80.1	9.0	6.7						
8032	19 52.6	6.8	9.0	.....	30 53.2	+ 2 12.3	−0.0	.....	5.5

Observations and computations for latitude of Fort Whipple, Arizona—Continued.

OCTOBER 31, 1871.

Number of star.	Micrometer-readings.	Level. N.	Level. S.	Remarks.	Half sum of declination.	Corrections. Micrometer and reference.	Corrections. Level.	Corrections. Meridian.	Latitude.
	t. d.				° ′ ″	′ ″	″		° ′ ″
8097	18 95.0	8.8	7.4	Very faint					
8128	26 65.6	7.6	8.9	.....	34 27 54.3	+ 5 11.4	+0.1	.....	34 33 5.8
8158	25 30.6	7.0	9.1						
8182	15 63.3	5.7	10.5	.....	26 41.2	+ 6 30.9	−4.7	.....	7.4
8195	16 77.6	9.9	6.4	*d.*					
8206	19 1.6	2.3	8.8	(!) Is 7.3.	34 36.6	− 1 30.5	+1.3	.....	7.4
8250	15 23.6	7.5	8.8						
8280	24 60.5	13.1	3.2	.....	26 39.4	+ 6 18.6	+5.8	.....	3.8
8299	20 47.1	9.0	7.4						
8307	15 25.9	7.4	9.0	.....	36 37.3	− 3 30.6	0.0	.....	6.7
8317	12 23.1	12.1	4.3						
8370	24 74.4	6.5	10.2	.....	41 31.6	− 8 25.6	+2.8	.....	8.8
48	18 65.5	8.1	9.0						
92	17 12.2	8.9	8.3	.....	34 8.0	−1 2.0	−0.2	.....	5.8
116	13 34.4	10.1	7.0						
122	12 70.9	10.1	7.0	.....	23 47.4	+ 9 17.2	+0.5	.....	5.1
146	27 13.2	7.5	9.8	.....	23 20.0	+ 9 42.9	+0.5	.....	3.4
166	16 15.2	5.1	12.2						
173	24 68.0	7.1	10.2	.....	27 29.2	+ 5 44.6	−6.9	.....	6.9
201	13 60.2	7.2	10.0						
211	22 20.8	8.8	8.4	.....	38 55.7	− 5 47.8	−1.6	.....	6.3
232	14 84.4	11.5	6.0						
235	11 95.0	11.9	5.6	.....	39 8.6	− 5 58.3	−1.9	.....	8.4
247	23 71.1	4.6	12.9	.....	41 4.0	− 7 55.3	−1.3	.....	7.4

NOVEMBER 1, 1871.

7275	12 41.5	8.5	7.0						
7301	23 26.0	7.9	7.9	.....	34 25 46.6	+ 7 18.3	+1.0	.....	34 33 5.9
7345	18 26.2	8.4	7.8	.....	29 9.4	+ 3 56.3	+1.4	.....	7.1
7372	16 48.8	8.1	8.0						
7387	18 31.4	7.2	9.1	.....	31 53.6	+ 1 13.8	−1.2	.....	6.2
7520	24 34.6	8.3	8.7						
7560	13 19.6	9.7	8.1	.....	40 36.0	− 7 30.6	+0.8	.....	6.2
7749	18 51.3	6.1	12.1						
7796	19 82.7	10.1	8.2	.....	34 2.2	− 0 53.1	−2.8	.....	6.3
7807	18 14 0	10.3	8.4						
7820	21 29.7	7.8	12.1	.....	30 58.8	+ 2 7.6	−1.6	.....	4.8
7915	18 86.8	9.0	10.0						
7923	19 26.0	9.6	9.6	.....	33 22.7	− 0 15.8	−0.7	.....	6.2
7943	17 40.3	6.1	12.8						
7953	7 44.5	13.0	5.9	.....	39 48.8	− 6 42.4	+0.3	.....	6.7
8023	22 93.0	9.5	9.8						
8032	19 60.4	8.6	10.9	.....	30 53.3	+ 2 10.8	+1.4	.....	5.5
8076	20 43.1	10.6	8.9						
8079	16 51.0	8.3	11.1	.....	30 27.6	+ 2 38.5	−0.7	.....	5.4
8097	18 85.0	9.0	10.8						
8128	26 55.5	9.8	10.1	.....	27 54.3	+ 5 11.4	−1.4	.....	4.5
8195	16 6.4	10.5	9.2						
8206	18 31.1	9.2	10.6	.....	34 36.7	− 1 30.8	−0.1	.....	5.8
8299	20 12.4	8.0	12.1						
8307	14 24.0	13.7	6.7	.....	36 37.6	− 3 33.5	+2.0	.....	6.1

Observations and computations for latitude of Fort Whipple, Arizona—Continued.

NOVEMBER 1, 1871.

Number of star.	Micrometer-readings.	Level. N.	Level. S.	Remarks.	Half sum of declination.	Corrections. Micrometer and reference.	Corrections. Level.	Corrections. Meridian.	Latitude.
	t. d.				° ′ ″	′ ″	″		° ′ ″
8317	12 2.6	10.2	9.7						
8370	24 52.1	10.1	10.0	.....	34 41 31.7	− 8 24.9	+0.4	.....	34 33 7.2
4	11 66.2	10.0	10.3						
28	29 3.5	8.8	11.7	.....	21 24.6	+11 42.1	−2.2	.....	4.5
48	18 46.4	11.8	8.7						
92	16 96.2	8.0	12.7	.....	34 8.2	− 1 0.7	−1.1	.....	6.4
116	13 42.1	9.0	12.0						
122	12 76.1	9.0	12.0	.....	23 47.5	+ 9 19.4	−1.7	.....	5.2
146	27 26.5	10.5	10.0	.....	23 20.2	+ 9 46.1	−1.7	.....	4.6
166	16 27.3	8.4	12.9						
173	24 66.3	11.2	10.0	.....	27 29.4	+ 5 39.0	−2.2	.....	6.2
201	12 93.5	9.5	11.8						
211	21 52.0	10.8	10.8	.....	38 56.0	− 5 46.9	−1.6	.....	7.5
232	15 9.0	10.6	10.6						
235	12 20.2	10.6	10.6	.....	39 8.7	− 5 59.6	−2.3	.....	6.8
247	23 99.0	9.0	12.4	.....	41 4.1	− 7 56.3	−2.3	.....	5.5

NOVEMBER 2, 1871.

8250	15 30.3	9.2	12.4						
8280	24 96.0	8.3	13.5	.....	34 26 39.6	+ 6 30.2	−5.7	.....	34 33 4.1
4	11 88.0	10.4	12.0						
28	29 27.8	10.5	12.0	.....	21 24.7	+11 43.1	−2.1	.....	5.7
116	13 23.0	10.4	12.0						
146	27 5.6	10.5	12.0	.....	23 47.6	+ 9 18.6	−2.1	.....	4.1
166	16 83.1	10.7	12.4						
173	25 18.5	12.0	10.5	.....	27 29.5	+ 5 37.6	−0.1	.....	7.0
201	13 60.5	9.8	13.0						
211	22 27.2	13.6	9.0	.....	38 56.0	− 5 50.2	+0.9	.....	6.7
214	19 52.0	19.5	3.0						
219	17 52.9	− 0.5	22.7	Very faint	34 26.9	− 1 20.5	−0.8	.....	5.6
232	15 78.7	11.6	10.9						
235	12 91.8	12.0	10.7	.....	39 8.9	− 6 12.0	+9.0	.....	5.9
247	24 99.3	17.6	5.0	.....	41 4.2	− 8 8.0	+9.4	.....	5.6

NOVEMBER 5, 1871.

8097	19 39.7	9.8	8.1	Very faint					
8128	27 1.4	10.2	7.5	.....	34 27 55.0	+ 5 7.8	+3.0	.....	34 33 5.8
8136	17 87.9	12.9	4.8						
8159	20 82.6	7.0	10.7	.....	35 2.3	− 1 59.1	+3.0	.....	6.2
8250	15 54.8	10.3	7.6						
8280	25 4.0	8.6	9.8	.....	26 40.0	+ 6 23.6	+1.0	.....	4.6
8299	20 68.0	9.0	9.1	Very faint					
8307	15 41.8	11.3	7.2	.....	36 37.8	− 3 32.6	+2.7	.....	7.8
8317	13 11.2	7.5	11.0						
8370	25 66.7	12.6	6.1	.....	41 32.2	− 8 27.4	+2.0	.....	6.8
4	12 8.5	11.5	7.3						
28	29 32.0	9.9	8.9	.....	21 25.1	+11 36.5	+3.5	.....	5.1
214	19 18.2	11.0	8.1						
219	17 7.0	10.4	9.0	.....	34 27.3	− 1 25.3	+2.9	.....	4.9

Mean latitude of Fort Whipple, Arizona, 34° 33′ 6″.124 ±0.065.

FORT FRED STEELE, WYOMING, (1872.)

Longitude, 106° 56′ 42″.80; latitude, 41° 46′ 40″.24 ±0″.05.

The point selected for the station at Fort Fred Steele was just in the rear of the sutler's store, on the west side of the railroad-track. Being across a ravine which lay between it and the railroad, it was entirely free from the jar of passing trains; and being at the same time to the windward, there was no interference from smoke. Fort Fred Steele is a military post pure and simple, is situated on the left bank of the North Platte, where the Union Pacific Railroad crosses it, and has no citizen-population whatever, if the few railroad employés and the proprietors of one or two insignificant ranches in the immediate vicinity be excepted. The location is on a bluff of the river, which presents here limited and rather barren valleys, while the surrounding country has been much disturbed by volcanic action, and, subsequently, further cut up by erosion. The general view is very limited; the top of Elk Mountain can be seen at the southeast and directly north on the east side of the river, and but two or three miles distant a rocky ridge, around which the river works its way to the west. Southward the view is up the valley of the river, the barrenness of which is somewhat relieved by a few straggling cotton-wood trees. Taken altogether, its surroundings are not inviting, and, if we except the country about Green River, no region which the Union Pacific Railroad traverses is more destitute of animal and vegetable life.

Meteorological.—The most unfavorable condition possible as to weather prevailed during the occupation of this station, which was in the month of November. In this time there was scarcely a week altogether that could be made available for astronomical work in connection with Salt Lake. It was entirely too cold to make anything like satisfactory observations, the thermometer showing frequently a range of temperature from 30° to 40° below freezing, and once it actually touched 60°, when it was no longer possible to remain in the tent or keep the ink and battery from freezing, despite the use of a stove—a very objectionable feature to an observatory under any circumstances. It was not only cold, but an almost uninterrupted series of drifting snow and dust storms succeeded each other.

Observatory and instruments.—The observatory and instruments were the same as those used at Cheyenne, Wyo., and the transit was mounted in the same way. The assistants, (J. H. Clark being the principal.) were also the same. The telegraphic work was done over the Atlantic and Pacific line, and the operators were Messrs. Brown, McCoy, Murphy, and three others. These were not all present at the same time, but came as reliefs during the occupancy of this station.

Connections.—Connection was made with Salt Lake observatory. On the 1st, 4th, 5th, 7th, 19th, 20th, 21st, 22d, 25th, and 26th of November, observations were made with the view of interchanging signals for longitude, and chronometer-signals were sent and received on six nights. For eleven nights, work was prosecuted on the latitude. On many of them only a pair or two of stars here and there between the passing storm-clouds could be observed.

Instrumental values.—The instrumental values are given in the report on Cheyenne station already published.

Circumstances of telegraphic connection.—The length of the circuit is about four hundred miles. The observatory was connected by a loop with the railroad telegraph-office, and all the signals were received and

sent by the instrumentality of the chronograph. No information is available as to the batteries and repeaters on the circuit employed,

The computations were made by civilian assistants, J. H. Clark and Dr. F. Kampf. The arrangement into publication form was made by the latter.

Uniform tables of time-reductions at Fort Fred Steele, Wyo., November 5, 1872.

Name of star.	Clamp.	T	*b* B	*a* A	*c* C	T′	AR.	Δ T
		h. m. s.	*s.*	*s.*	*s.*	*h. m. s.*	*h. m. s.*	*h. m. s.*
ε Pegasi	W.	23 38 16.20	−0.28	+ 2.37	−0.04	23 38 18.25	21 37 55.64	−2 00 22.61
11 Cephei		40 32.96	−0.87	− 6.45	−0.12	40 25.52	40 02.79	22.73
μ Capricorni		46 40.04	−0.19	+ 3.73	−0.04	46 43.54	46 20.92	22.62
79 Draconis		51 48.27	−0.41	− 7.86	−0.13	51 39.87	51 16.95	22.92
α Aquarii		59 34.12	+0.04	+ 2.99	−0.04	59 37.11	59 14.42	22.69
32 Urs. Maj., L.C.	E.	0 08 58.09	+0.04	+10.18	−0.10	0 09 08.21	22 08 44.65	23.56
π Aquarii		19 06.25	−0.04	+ 2.90	+0.04	19 09.15	18 46.36	22.79
9 Draconis, L. C		24 17.43	+0.20	+16.42	−0.17	24 33.88	24 11.01	22.87
η Draconis		29 08.83	−0.10	+ 2.99	+0.04	29 11.76	28 48.74	23.02
ζ Pegasi		35 27.42	−0.17	+ 2.33	+0.04	35 29.62	35 06.65	−2 00 22.97
Mean for 22h 0m local sidereal time								−2 00 22.88

Normal equations.

$$\begin{aligned} 10\ \delta t - 6.74\ a - 13.16\ c &= +30.82 \\ -6.74\ \delta t + 27.38\ a + 11.12\ c &= -121.02 \qquad a = -4^s.390 \\ -13.16\ \delta t + 11.12\ a + 51.01\ c &= -49.81 \qquad c = +0^s.035 \end{aligned}$$

Fort Fred Steele, Wyo., November 5, 1872.

Name of star.	Clamp.	T	*b* B	*a* A	*c* C	T′	AR.	Δ T
		h. m. s.	*s.*	*s.*	*s.*	*h. m. s.*	*h. m. s.*	*h. m. s.*
ε Piscium	E	1 33 43.92	+0.07	+ 2.68	0.00	1 33 46.67	23 33 24.44	−2 00 22.23
Groomb. 4163		49 12.05	+0.21	− 8.45	−0.01	49 03.80	48 41.34	22.46
ω Piscium		53 06.65	+0.04	+ 2.64	0.00	53 09.33	52 46.80	22.53
α Adrom		2 02 10.38	+0.05	+ 1.16	0.00	2 02 11.59	0 01 48.95	22.64
4 Drac., L. C		06 12.13	−0.12	+19.09	+0.02	06 31.12	06 08.90	22.22
α Cassiopeiæ	W.	33 43.22	−0.04	− 1.92	0.00	33 41.26	33 18.58	22.68
β Ceti		37 31.54	+0.05	+ 4.11	0.00	37 35.70	37 12.51	23.19
32 Camel., L. C		47 51.86	−0.57	+35.27	−0.03	47 26.53	48 04.97	22.56
ε Piscium		56 40.98	+0.08	+ 2.55	0.00	56 43.61	56 20.77	22.84
Mean for 0h 0m local sidereal time								−2 00 22.59

Normal equations.

$$\begin{aligned} 9\ \delta t - 12.78\ a + 7.66\ c &= +60.50 \\ -12.78\ \delta t + 86.18\ a - 49.74\ c &= -389.94 \qquad a = -4^s.470 \\ +7.66\ \delta t - 49.74\ a + 140.57\ c &= +224.57 \qquad c = -0^s.003 \end{aligned}$$

Fort Fred Steele, November 19, 1872.

Name of star.	Clamp.	T	*b* B	*a* A	*c* C	T′	AR.	Δ T
		h. m. s.	*s.*	*s.*	*s.*	*h. m. s.*	*h. m. s.*	*h. m. s.*
ζ Pegasi	W.	0 34 32.85	− 0.44	+ 0.93	− 0.50	0 34 32.84	22 35 06.47	−1 59 26.37
ι Cephei		44 39.27	− 1.16	− 1.71	− 1.19	44 35.21	45 08.90	26.31
α Piscis Australis		50 02.05	− 0.19	+ 1.94	− 0.57	50 03.23	50 36.74	26.49
α Ursæ Majoris, L. C		55 12.13	+ 0.33	+ 3.70	+ 1.07	55 17.23	55 50.44	26.79
ο Cephei		1 12 56.31	− 1.69	− 1.99	− 1.29	1 12 51.34	23 13 24.57	26.77
θ Piscium		20 57.12	− 0.57	+ 1.04	− 0.50	20 57.09	21 30.63	26.46
γ Cephei	W.	33 45.03	− 2.56	− 4.47	− 2.19	33 35.81	33 69.15	26.66
α Cassiopeiæ	E.	2 32 46.48	− 1.78	− 0.76	+ 0.88	2 32 44.82	0 33 18.38	26.44
β Ceti		36 37.46	− 0.54	+ 1.62	+ 0.52	36 39.06	37 12.43	26.63
ε Piscium		55 46.54	− 0.86	+ 1.00	+ 0.50	55 47.18	56 20.74	−1 59 26.44
Mean for 23h 0m local sidereal time								−1 59 26.44

Normal equations.

$$10\ \delta t - 0.74\,a - 6.61\,c = -7.33$$
$$-0.74\,\delta t + 16.27\,a - 19.42\,c = -37.82 \qquad a = -1^s.758$$
$$-6.61\,\delta t - 19.42\,a + 45.50\,c = +60.16 \qquad c = +0^s.495$$

Fort Fred Steele, November 20, 1872.

Name of star.	Clamp.	T	*b* B	*a* A	*c* C	T′	AR.	Δ T
		h. m. s.	*s.*	*s.*	*s.*	*h. m. s.*	*h. m. s.*	*h. m. s.*
θ Piscium	E.	1 20 50.90	− 0.28	+ 2.63	− 0.41	1 20 53.66	23 21 30.62	−1 59 23.04
γ Cephei		33 42.87	− 1.23	−11.30	1.78	33 32.12	33 69.08	23.04
α Cassiopeiæ	W.	2 32 44.71	− 0.69	− 1.91	− 0.72	2 32 41.39	0 33 18.35	23.04
Mean for 0h 0m local sidereal time								−1 59 23.04

Normal equations.

$$+3\ \delta t + 2.38\,a + 3.65\,c = -9.23$$
$$+2.38\,\delta t + 6.98\,a + 9.86\,c = -27.20 \qquad a = -4^s.452$$
$$+3.65\,\delta t + 9.86\,a + 23.73\,c = -34.48 \qquad c = \ldots\ 0^s.403$$

Fort Fred Steele, November 21, 1872.

Name of star.	Clamp.	T	*b* B	*a* A	*c* C	T′	AR.	Δ T
		h. m. s.	*s.*	*s.*	*s.*	*h. m. s.*	*h. m. s.*	*h. m. s.*
α Aquarii	W.	23 58 30.00	−0.12	+ 2.64	−0.38	23 58 32.14	21 59 14.22	−1 59 17.92
32 Ursæ Majoris, L. C.		0 07 53.67	+0.15	+ 9.00	+0.91	0 08 03.73	22 08 45.72	18.01
π Aquarii		18 02.05	−0.18	+ 2.56	−0.38	18 04.05	18 46.16	17.99
9 Draconis (H.)		23 14.17	+0.60	+14.51	+1.59	23 30.87	24 12.70	18.17
γ Aquarii		28 04.42	−0.19	+ 2.64	−0.38	28 06.49	28 48.55	17.94
226 Cephei		29 30.59	−0.73	− 8.65	−1.51	29 19.70	29 61.20	18.41
ζ Pegasi		34 22.83	−0.16	+ 2.06	−0.38	34 24.35	35 06.45	17.90
π Aquarii	E.	45 13.18	−0.34	+ 3.03	+0.38	45 16.27	45 58.10	18.17
α Piscis Australis		49 50.12	−0.19	+ 4.27	+0.44	49 54.64	50 36.71	17.93
α Ursæ Majoris, L. C.		55 01.30	−0.28	+ 8.15	−0.81	55 08.36	55 50.56	17.98
α Pegasi		57 41.12	−0.50	+ 1.82	+0.39	57 42.83	58 25.07	17.76
ι Piscium		1 32 39.65	−0.44	+ 2.33	+0.38	1 32 41.92	23 33 24.29	17.63
γ Cephei		33 36.89	−2.02	− 9.86	+1.66	33 26.67	33 69.01	−1 59 17.68
Mean for 22h 30m local sidereal time								−1 59 17.94

Normal equations.

$$13\ \delta t - 8.89\,a + 5.09\,c = +37.50$$
$$-8.89\,\delta t + 39.24\,a - 15.28\,c = -158.95 \qquad a = -3^s.880$$
$$5.09\,\delta t - 15.28\,a + 72.72\,c = +90.21 \qquad c = +0^s.375$$

Fort Fred Steele, November 22, 1872.

Name of star.	Clamp.	T	*b* B	*a* A	*c* C	T′	AR.	Δ T
		h. m. s.	*s.*	*s.*	*s.*	*h. m. s.*	*h. m. s.*	*h. m. s.*
9 Draconis, L. C	W.	0 23 18.72	0.12	+8.75	0.00	0 23 27.59	22 24 12.81	−1 59 14.78
226 Cephei		29 20.84	−0.20	−5.22	0.00	29 15.42	29 61.20	14.22
ι Cephei		44 25.84	−0.30	−2.27	0.00	44 23.27	45 08.78	14.49
α Ursæ Majoris, L. C.		54 59.83	+0.05	+4.91	0.00	55 04.79	55 50.62	14.17
o Cephei		1 12 41.38	−0.20	−2.65	0.00	1 12 38.53	23 13 24.41	14.12
λ Draconis, L. C		22 55.62	+0.08	6.37	0.00	23 02.07	23 48.22	13.93
γ Cephei		33 29.63	−0.25	−5.94	0.00	33 23.44	33 68.88	−1 59 14.56
Mean for 23h 0m local sidereal time								−1 59 14.31

Normal equations.

$$7\ \delta t - 1.69\,a - 4.12\,c = +1.76$$
$$-1.69\,\delta t + 39.44\,a - 53.84\,c = -91.94 \qquad a = -2^s.345$$
$$-4.12\,\delta t - 53.84\,a + 79.50\,c = -127.58 \qquad c = 0^s.000$$

Fort Fred Steele, November 22, 1872.

Name of star.	Clamp.	T	*b* B	*a* A	*c* C	T′	AR.	Δ T
		h. m. s.	*s.*	*s.*	*s.*	*h. m. s.*	*h. m. s.*	*h. m. s.*
κ Draconis	W.	2 27 07.19	+0.11	+ 6.48	+0.67	2 27 14.45	0 28 00.46	—1 59 13.99
α Cassiopeiæ		32 33.67	—0.17	— 1.01	—0.40	32 32.09	33 18.30	13.79
21 Cassiopeiæ		36 38.17	—0.32	— 4.66	—0.83	36 32.36	37 18.18	14.18
32 Camelop'rdalis	E.	47 04.43	+0.57	+18.46	—2.19	47 21.27	48 07.25	14.02
ε Piscium		55 33.60	—0.08	+ 1.33	0.23	55 35.08	56 20.71	14.37
38 Cassiopeiæ		3 21 05.61	—0.25	— 3.14	+0.65	3 21 02.87	1 21 48.97	—1 59 13.90
Mean for 0h 30m local sidereal time								—1 59 14.04

Normal equations.

$$\begin{aligned} 6\ \delta t - 7.47\ a - 8.34\ c &= 15.34 \\ -7.47\ \delta t + 76.18\ a + 63.73\ c &= -163.74 \\ -8.34\ \delta t + 63.73\ a + 129.86\ c &= -119.46 \end{aligned} \qquad \begin{aligned} a &= -2^s.340 \\ c &= +0^s.225 \end{aligned}$$

Fort Fred Steele, November 25, 1872.

Name of star.	Clamp.	T	*b* B	*a* A	*c* C	T′	AR.	Δ T
		h. m. s.	*s.*	*s.*	*s.*	*h. m. s.*	*h. m. s.*	*h. m. s.*
ι Cephei		0 44 13.50	—1.12	—2.03	+0.45	0 44 10.80	22 45 08.60	—1 59 02.20
α Piscis Aust.		49 36.43	—0.18	+2.30	+0.21	49 38.76	50 36.64	02.12
α Urs. Maj. (L.C.)		54 48.09	+0.27	+4.39	—0.40	54 52.31	55 50.79	01.52
ο Cephei		1 12 29.60	—1.17	—2.36	+0.48	1 12 26.55	23 13 24.28	02.27
θ Piscium		20 31.54	—0.40	+1.23	+0.19	20 32.56	21 30.56	02.00
ι Piscium		32 25.09	—0.35	+1.25	+0.19	32 26.18	33 24.25	01.93
Groom. 4163		47 46.42	—1.38	—3.95	0.66	47 41.75	48 40.24	01.51
μ Piscium		51 47.50	—0.37	+ 1.23	+0.19	51 48.55	52 46.63	01.92
α Andromedæ		2 00 50.32	—0.45	+ 0.54	+0.21	2 00 50.62	0 01 48.74	01.88
4 Draconis (L.C.)		04 03.82	+1.02	+ 8.92	—0.91	04 12.85	06 10.73	02.12
θ Ceti		3 16 41.14	—0.12	+1.63	—0.19	16 42.46	17 40.24	02.22
38 Cassiopeiæ		20 54.96	—0.76	—2.80	—0.53	20 50.87	21 48.91	01.96
γ Piscium		23 42.39	—0.31	+0.98	—0.19	23 42.87	24 40.90	01.97
ο Piscium		37 42.31	—0.31	+1.17	—0.19	37 42.98	38 41.05	01.93
β Arietis		46 38.92	—0.44	+ 0.82	—0.20	46 39.10	47 37.27	—1 59 01.83
Mean for 0h 0m local sidereal time								—1 59 01.96

Normal equations.

$$\begin{aligned} +15.00\ \delta t - 6.38\ a - 0.21\ c &= +13.83 \\ -6.38\ \delta t + 33.86\ a + 32.67\ c &= -64.88 \\ -0.21\ \delta t + 32.67\ a + 72.51\ c &= -54.83 \end{aligned} \qquad \begin{aligned} a &= -2^s.090 \\ c &= +0^s.185 \end{aligned}$$

Salt Lake, November 5, 1872.

Name of star.	Clamp.	T	*b* B	*a* A	*c* C	T′	AR.	Δ T
		h. m. s.	*s.*	*s.*	*s.*	*h. m. s.*	*h. m. s.*	*h. m. s.*
ο Cephi	W.	23 16 01.13	0.46	+ 5.09	0.08	23 16 05.84	23 13 25.09	—0 02 40.75
θ Piscium		24 14.06	0.07	— 2.52	+ 0.03	24 11.50	21 30.82	40.68
ω Piscium		36 07.59	0.10	— 2.57	+ 0.03	36 04.95	33 24.40	40.55
γ Cephei		36 40.31	0.62	+ 11.31	+ 0.13	36 51.13	34 10.29	40.84
Groom. 4163	E.	51 14.14	0.44	+ 8.44	0.11	51 22.03	48 41.35	40.68
ω Piscium		55 30.21	0.09	— 2.48	0.03	55 27.61	52 46.80	40.81
α Andromedæ		0 04 30.97	0.10	— 1.04	0.03	0 04 29.80	0 01 48.96	40.84
γ Pegasi		09 24.11	0.06	— 2.00	0.03	09 22.02	06 41.26	40.76
ι Ceti		15 41.21	0.02	— 3.39	0.03	15 37.81	12 56.96	—0 02 40.85
Mean for 23h 30m local sidereal time								—0 02 40.75

Normal equations.

$$\begin{aligned} +9.00\ \delta t - 2.49\ a + 1.27\ c &= +13.12 \\ -2.49\ \delta t + 13.78\ a - 8.53\ c &= -60.68 \\ +1.27\ \delta t - 8.53\ a + 45.30\ c &= +38.70 \end{aligned} \qquad \begin{aligned} a &= -4^s.346 \\ c &= +0^s.029 \end{aligned}$$

Salt Lake, November 19, 1872.

Name of star.	Clamp.	T	*b* B	*a* A	*c* C	T′	AR.	Δ T
		h. m. s.	*s.*	*s.*	*s.*	*h. m. s.*	*h. m. s.*	*h. m. s.*
θ Aquarii	W.	22 12 19.55	−0.15	−0.35	+0.04	22 12 19.09	22 10 06.54	0 02 12.55
π Aquarii		20 59.27	−0.12	0.29	+0.04	20 58.90	18 46.19	12.71
9 Draconis, L. C		26 27.29	+0.13	−1.71	−0.17	26 25.54	24 12.22	13.32
226 Cephei		32 13.80	−0.30	+1.05	−0.16	32 14.71	30 01.39	13.32
ζ Pegasi		37 19.55	−0.12	−0.24	0.04	37 19.23	35 06.53	12.70
ι Cephei	E.	43 21.71	−0.21	+0.46	−0.09	43 21.87	45 08.89	12.98
λ Aquarii		48 11.40	−0.07	−0.35	−0.04	48 10.94	45 58.17	12.77
α Pegasi		23 00 38.24	−0.18	−0.21	−0.04	23 00 37.81	58 25.10	12.71
φ Aquarii		9 56.96	−0.14	−0.34	−0.04	09 56.44	23 07 43.74	12.70
ο Cephei		15 37.22	−0.46	+0.53	−0.10	15 37.19	13 24.50	−0 02 12.69
Mean, excluding 9 Draconis and 226 Cephei								−0 02 12.84
Mean for 22h. 30m. local sidereal time								−0 02 12.74

Normal equations.

$$+10.00\,\delta t + 3.19\,a - 5.25\,c = -0.17$$
$$+3.19\,\delta t + 24.29\,a - 19.60\,c = -11.45 \qquad a = -0^s.457.$$
$$-5.25\,\delta t - 19.60\,a + 52.59\,c = +10.57 \qquad c = +0^s.042$$

Salt Lake, November 19, 1872.

Name of star.	Clamp.	T	*b* B	*a* A	*c* C	T′	AR.	Δ T
		h. m. s.	*s.*	*s.*	*s.*	*h. m. s.*	*h. m. s.*	*h. m. s.*
α Andromedæ	E.	0 04 01.72	−0.32	−0.06	−0.10	0 04 01.24	0 01 48.83	−0 02 12.41
γ Pegasi		08 53.98	−0.28	−0.11	−0.09	08 53.50	06 41.16	12.34
12 Ceti		25 46.17	−0.21	−0.18	−0.09	25 45.69	23 32.92	12.77
α Cassiopeiæ	W.	35 30.98	−0.73	+0.11	−0.16	35 30.52	33 18.27	12.25
β Ceti		39 25.21	−0.10	−0.22	−0.09	39 24.98	37 12.46	12.52
32 Camelopardalis, L. C		50 20.52	+0.92	−1.97	−0.88	50 18.59	48 06.17	12.42
ε Piscium		58 33.47	−0.13	−0.14	+0.09	58 33.29	56 20.73	−0 02 12.56
Mean for 0h 30m local sidereal time								−0 02 12.47

Normal equations.

$$+7.00\,\delta t + 10.43\,a - 9.07\,c = +0.34$$
$$+10.43\,\delta t + 66.14\,a - 78.83\,c = -17.81 \qquad a = -0^s.246$$
$$-9.07\,\delta t - 78.83\,a + 103.96\,c = +23.82 \qquad c = +0^s.091$$

Salt Lake, November 20, 1872.

Name of star.	Clamp.	T	*b* B	*a* A	*c* C	T′	AR.	Δ T
		h. m. s.	*s.*	*s.*	*s.*	*h. m. s.*	*h. m. s.*	*h. m. s.*
π Aquarii	W.	22 20 56.45	−0.17	−0.27	+0.03	22 20 56.04	22 18 46.18	−0 02 09.86
9 Draconis, L. C		26 23.86	+0.40	−1.60	−0.11	26 22.55	24 12.32	10.23
226 Cephei		32 11.20	−0.66	+0.98	−0.11	32 11.63	30 01.31	10.32
ζ Pegasi		37 16.75	−0.16	−0.22	+0.03	37 16.40	35 06.52	09.88
λ Aquarii		48 08.30	−0.17	−0.33	+0.03	48 07.83	45 58.16	09.67
ο Cephei	E.	23 15 34.54	−0.62	+0.50	−0.07	23 15 34.35	23 13 24.45	09.90
θ Piscium		23 41.23	−0.22	−0.24	−0.03	23 40.74	21 30.67	10.07
γ Cephei		36 19.15	−0.97	+1.11	−0.12	36 19.17	34 09.22	09.95
ε Piscium		35 34.79	−0.22	−0.25	−0.03	35 34.29	33 24.26	−0 02 10.03
Mean for 23h 0m local sidereal time								−0 02 09.99

Normal equations.

$$+9.00\,\delta t + 0.77\,a - 6.19\,c = -0.39$$
$$+0.77\,\delta t + 29.42\,a - 9.54\,c = -12.82 \qquad a = -0^s.427$$
$$-6.19\,\delta t - 9.54\,a + 65.34\,c = +5.77 \qquad c = +0^s.027$$

Salt Lake, November 20, 1872.

	Name of star.	Clamp.	T	*b* B	*a* A	*c* C	T′	AR	Δ T
			h. m. s.	*s.*	*s.*	*s.*	*h. m. s.*	*h. m. s.*	*h. m. s.*
α	Andromedæ	E.	0 03 59.26	— 0.28	— 0.08	— 0.10	0 03 58.80	0 01 48.82	—00 02 9.98
γ	Pegasi		08 51.73	— 0.22	— 0.16	— 0.09	08 51.26	06 41.16	10.10
ι	Ceti		15 07.28	— 0.14	— 0.27	— 0.09	15 06.78	12 56.84	09.94
12	Ceti	W.	25 43.15	— 0.12	— 0.25	+ 0.09	25 42.87	23 32.91	09.96
α	Cassiopeiæ		35 28.16	— 0.22	+ 0.16	+ 0.15	35 28.25	33 18.25	10.00
β	Ceti		39 22.79	— 0.06	— 0.32	+ 0.09	39 22.50	37 12.45	—0 02 10.05
	Mean for 0h 0m local sidereal time								—0 02 10.00

Normal equations.

$$-6.00\,\delta t + 2.64\,a + 0.66\,c = -0.91$$
$$-2.64\,\delta t + 2.43\,a - 0.68\,c = -0.91 \qquad a = -0^s.351$$
$$-0.66\,\delta t - 0.68\,a + 8.72\,c = +0.99 \qquad c = +0^s.086$$

Salt Lake, November 21, 1872.

	Name of star.	Clamp.	T	*b* B	*a* A	*c* C	T′	AR	Δ T
			h. m. s.	*s.*	*s.*	*s.*	*h. m. s.*	*h. m. s.*	*h. m s.*
ξ	Pegasi	W.	22 37 14.76	— 0.22	— 0.35	+ 0.14	22 37 14.33	22 35 06.51	—0 02 07.82
ι	Cephei		47 16.32	— 0.59	+ 0.68	+ 0.33	47 16.74	45 08.80	07.94
α	Pegasi		23 00 33 24	— 0.25	— 0.30	+ 0.14	23 00 32.83	58 25.08	07.75
φ	Aquarii		09 52.01	— 0.16	— 0.50	+ 0.14	09 51.49	23 07 43.72	07.77
ο	Cephei	E.	15 32.32	— 0.46	+ 0.78	— 0.35	15 32.29	13 24.41	07.88
	Piscium		23 38.99	— 0.16	— 0.38	— 0.14	23 38.31	21 30.66	07.65
ι	Piscium		35 32.38	— 0.16	— 0.39	— 0.14	35 31.69	33 24.25	07.44
γ	Cephei		36 16.64	— 0.72	+ 1.73	— 0.61	36 17.04	34 09.14	—0 02 07.90
	Mean for 23h 0m local sidereal time								—0 02 07.77

Normal equations.

$$+8.00\,\delta t - 1.92\,a - 3.54\,c = +2.63$$
$$-1.92\,\delta t + 10.92\,a + 12.78\,c = -5.07 \qquad a = -0^s.664$$
$$-3.54\,\delta t + 12.78\,a + 37.43 = -4.19 \qquad c = +0^s.137$$

Salt Lake, November 21, 1872.

	Name of star.	Clamp.	T	*b* B	*a* A	*c* C	T′	AR.	Δ T
			h. m. s.	*s.*	*s.*	*s.*	*h. m. s.*	*h. m. s.*	*h. m. s.*
α	Andromedæ	E.	0 03 56.88	— 0.34	— 0.13	— 0.02	0 03 56.39	0 01 48.81	—0 02 07.58
γ	Pegasi		08 49.33	— 0.28	— 0.24	— 0.02	08 48.79	06 41.14	07.65
ι	Ceti		15 05.16	— 0.18	— 0.42	— 0.02	15 04.54	12 56.76	07.78
α	Cassiopeiæ	W.	35 25.70	— 0.38	+ 0.25	+ 0.03	35 25.60	33 18.23	07.37
β	Ceti		39 20.53	— 0.09	— 0.49	+ 0.02	39 19.97	37 12.44	07.53
32	Camelop. L.C.		50 17.64	+ 0.90	— 4.33	— 0.18	50 14.03	48 06.53	07.50
ε	Piscium		58 28.78	— 0.14	— 0.30	+ 0.02	58 28.36	56 20.72	—0 02 07.64
	Mean for 0h 0m local sidereal time								—0 02 07.58

Normal equations.

$$+7.00\,\delta t - 10.47\,a - 9.08\,c = -2.88$$
$$-10.47\,\delta t + 66.21\,a - 78.92\,c = -32.53 \qquad a = -0^s.541$$
$$-9.08\,\delta t - 78.92\,a + 104.02\,c = +40.66 \qquad c = +0^s.018$$

Salt Lake, November 22, 1872.

Name of star.	Clamp.	T	*b* B	*a* A	*c* C	T′	AR.	ΔT
		h. m. s.	*s.*	*s.*	*s.*	*h. m. s.*	*h. m. s.*	*h. m. s.*
π Aquarii	W.	22 20 52.18	— 0.22	— 0.30	+ 0.03	22 20 51.69	22 18 46.17	—0 02 05.52
226 Cephei		32 06.86	— 1.02	+ 1.08	+ 0.12	32 07.04	30 01.13	05.91
ζ Pegasi		37 12.47	— 0.27	— 0.25	+ 0.03	37 11.98	35 06.50	05.48
ι Cephei		47 13.93	— 0.59	+ 0.48	+ 0.07	47 13.89	45 08.75	05.14
λ Aquarii		48 04.16	— 0.15	— 0.36	+ 0.03	48 03.68	45 58.14	05.54
α Pegasi	E.	23 00 30.98	— 0.07	— 0.21	— 0.03	23 00 30.67	58 25.07	05.60
φ Aquarii		09 49.85	— 0.01	— 0.35	— 0.03	09 49.46	23 07 43.72	05.74
o Cephei		15 29.60	+ 0.07	+ 0.55	— 0.08	15 30.14	13 24.36	05.78
θ Piscium		23 36.69	+ 0.04	— 0.27	— 0.03	23 36.43	21 30.64	05.79
γ Cephei		36 13.19	+ 0.18	+ 1.23	— 0.13	36 14.47	34 09.05	—0 02 05.42
Mean for 23h 0m local sidereal time								—0 02 05.59

Normal equations.

$$+ 10.00\,\delta t - 3.39\,a - 0.63\,c = - 4.34$$
$$- 3.39\,\delta t + 16.81\,a + 3.15\,c = - 5.87 \qquad a = - 0^s.473$$
$$- 0.63\,\delta t + 3.15\,a + 54.55\,c = + 0.64 \qquad c = + 0^s.032$$

Salt Lake, November 25, 1872.

Name of star.	Clamp.	T	*b* B	*a* A	*c* C	T′	AR.	ΔT
		h. m. s.	*s.*	*s.*	*s.*	*h. m. s.*	*h. m. s.*	*h. m. s.*
226 Cephei	W.	22 31 58.88	+ 0.06	+ 0.68	+ 0.21	22 31 59.83	22 30 00.88	—0 01 58.97
ζ Pegasi		37 05.63	+ 0.01	— 0.15	+ 0.05	37 05.54	35 06.46	59.08
ι Cephei		47 06.96	+ 0.06	+ 0.30	+ 0.12	47 07.44	45 08.61	58.83
λ Aquarii		47 57.30	+ 0.04	— 0.23	+ 0.05	47 57.16	45 58.11	59.05
α Pegasi		23 00 24.06	+ 0.02	— 0.13	+ 0.05	23 00 24.00	58 25.03	58.97
φ Aquarii	E.	09 42.89	+ 0.05	— 0.22	— 0.05	09 42.67	23 07 43.70	59.00
o Cephei		15 22.82	+ 0.14	+ 0.35	— 0.13	15 23.18	13 24.22	58.96
θ Piscium		23 29.51	+ 0.04	— 0.17	— 0.05	23 29.33	21 30.61	58.72
ι Piscium		35 23.34	+ 0.04	— 0.18	— 0.05	35 23.15	33 24.21	58.94
γ Cephei		36 07.12	+ 0.14	+ 0.78	— 0.23	36 07.81	34 08.82	—0 01 58.99
Mean for 23h 0m local sidereal time								—0 01 58.82

Normal equations.

$$+ 10.00\,\delta t - 3.44\,a - 0.55\,c = + 1.53$$
$$- 3.44\,\delta t + 16.75\,a + 2.85\,c = - 5.03 \qquad a = - 0^s.298$$
$$- 0.55\,\delta t + 2.85\,a + 54.55\,c = + 1.96 \qquad c = + 0^s.052$$

Salt Lake chronometer.

NEGUS 1511.

1872.	Local sidereal time.	Correction of chronometer.	Adopted hourly rates.
	h.	*m. s.*	*s.*
November 5	23.5	—2 40.75	0.017
November 7	22.5	39.96	0.026
November 19	23.5	12.61	0.101
November 20	23.5	10.00	0.105
November 21	23.5	07.68	0.092
November 22	23.0	—2 05.59	0.090
November 25	23.0	—1 58.95	0.112
November 26	23.0	55.78	0.132

Fort Fred Steele chronometer.

NEGUS 1499.

1872.	Local sidereal time.	Correction of chronometer.	Adopted hourly rates.
	h.	*h. m. s.*	*s.*
November 5	23.0	−2 00 22.70	0.129
November 7	22.5	16.52	0.140
November 19	23.0	−1 59 26.54	0.150
November 20	24.0	23.04	0.180
November 21	22.5	17.93	0.181
November 22	23.5	14.16	0.161
November 25	0.0	59 01.96	0.201
November 26	22.5	−1 58 56.40	0.232

NOVEMBER 5, 1872.

Signals sent from Salt Lake.

Ft. Fred Steele chronometer.			Salt Lake chronometer.			Ft. Fred Steele chronometer.			Salt Lake chronometer.			Ft. Fred Steele chronometer.			Salt Lake chronometer.		
h.	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*
1	03	40.4	22	46	10.7	1	05	30.7	22	48	01.1	1	07	20.9	22	49	51.1
		50.4			20.8			40.7			11.1			31.2		50	01.4
	04	00.2			30.6			50.6			20.9			41.2			11.4
		10.2			40.6		6	01.0			31.1			51.1			21.2
		20.3			50.7			10.6			40.9		08	00.7			31.1
		30.7		47	01.1			20.7			51.0			11.0			41.1
		40.6			10.9			30.9		49	01.1			21.0			51.3
		50.4			20.8			40.9			11.1			31.4		51	01.7
	05	00.5			30.8			50.7			21.1			41.0			11.3
		10.4			40.7		07	00.7			31.0						
		20.4			50.8			10.7			41.1	Mean,	1	6 10.71	22	48	41.02

Signals sent from Fort Fred Steele.

Ft. Fred Steele chronometer.			Salt Lake chronometer.			Ft. Fred Steele chronometer.			Salt Lake chronometer.			Ft. Fred Steele chronometer.			Salt Lake chronometer.		
h.	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*
1	10	06.1	22	52	36.3	1	12	06.7	22	54	37.1	1	14	07.5	22	56	37.9
		17.1			47.3			17.3			47.7			16.8			47.1
		27.6			58.0			27.0			57.4			27.7			58.1
		35.8		53	06.3			36.1		55	06.4			36.6		57	07.0
		46.0			16.3			47.9			18.2			47.2			17.8
		56.1			26.3			56.6			27.0			57.2			27.8
	11	06.5			36.8		13	07.3			37.8		15	07.5			38.0
		17.0			47.3			17.1			47.4			17.2			47.6
		26.4			56.9			27.0			57.4			27.4			57.9
		36.1		54	06.3			36.8		56	07.2						
		46.7			16.1			47.2			17.7	Mean,	1	12 46.88	22	55	17.23
		56.6			27.0			57.0			27.3						

NOVEMBER 19, 1872.

Signals sent from Salt Lake.

Ft. Fred Steele chronometer.			Salt Lake chronometer.			Ft. Fred Steele chronometer.			Salt Lake chronometer.			Ft. Fred Steele chronometer.			Salt Lake chronometer.		
h.	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*
2	00	28.3	23	43	27.6	2	02	18.0	23	45	16.7	2	04	08.3	23	47	07.1
		38.1			36.9			28.2			26.9			18.3			17.1
		48.2			46.9			38.2			36.9			28.6			27.1
		58.0			56.8			48.3			47.1			38.7			37.2
	01	08.2		44	06.9			58.2			56.9			48.7			47.2
		17.9			16.6		03	08.1		46	06.9			58.7			57.2
		27.8			26.3			18.3			17.0		05	08.6		48	07.2
		38.2			36.9			28.3			26.9			18.7			17.3
		48.3			47.0			38.3			37.1			28.6			27.2
		58.1			56.8			48.7			47.2						
	02	07.9		45	06.7			58.3			57.1	Mean,	2	02 58.30	23	45	56.97

Signals sent from Fort Fred Steele.

Ft. Fred Steele chronometer.			Salt Lake chronometer.			Ft. Fred Steele chronometer.			Salt Lake chronometer.			Ft. Fred Steele chronometer.			Salt Lake chronometer.		
h.	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*		*h.*	*m.*	*s.*	*h.*	*m.*	*s.*
2	07	33.8	23	50	32.6	2	09	24.6	23	52	23 3		2	11	14.6	23	54	12 3
		43.5			42.2			34.2			33.0				24.9			23 [illegible]
		53.6			52.3			43.7			42.5				34.8			33.7
	08	03.2		51	02.0			54.1			52.9				43.8			42.6
		14.0			12.9		10	03.2		53	01.8				53.3			53.1
		24.7			23.3			14.5			13.2			12	03.5		55	02.1
		34.4			33.1			24.6			23.3				14.8			13.3
		43.7			42.3			34.5			33.2				25.0			23.9
		53.7			52.3			44.0			42.8				34.9			33.8
	09	03.4		52	02.1			54.5			53.1							
		14.6			12.2		11	03.3		54	02.0	Mean,	2	10	03.11	23	53	01.84

NOVEMBER 20, 1872.

Signals sent from Salt Lake.

Ft. Fred Steele chronometer.			Salt Lake chronometer.			Ft. Fred Steele chronometer.			Salt Lake chronometer.			Ft. Fred Steele chronometer.			Salt Lake chronometer.		
h.	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*		*h.*	*m.*	*s.*	*h.*	*m.*	*s.*
2	55	17.7	23	38	16.9	1	57	07.5	23	40	06.8		1	58	57.8	23	41	57.0
		27.3			26.5			17.5			16.8			59	07.8		42	07.0
		37.6			36.9			27.8			27.0				17.8			17.0
		47.6			46.9			37.8			37.1				28.0			27.2
		57.1			56.2			47.8			47.1				38.1			37.3
	56	07.1		39	06.3			57.8			56.9				48.2			47.4
		17.3			16.5		58	07.6		41	06.9				58.0			57.2
		27.6			26.9			17.5			16.8		2	00	08.0		43	07.1
		37.8			37.0			28.0			27.1				17.8			17.0
		47.8			47.0			38.1			37.2							
		57.5			56.8			47.7			47.1	Mean,	1	57	47.71	23	40	46.93

Signals sent from Fort Fred Steele.

Ft. Fred Steele chronometer.			Salt Lake chronometer.			Ft. Fred Steele chronometer.			Salt Lake chronometer.			Ft. Fred Steele chronometer.			Salt Lake chronometer.		
h.	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*		*h.*	*m.*	*s.*	*h.*	*m.*	*s.*
2	01	19.5	23	44	18.8	2	03	10.5	23	46	09.9		2	05	01.1	23	42	00.3
		30.5			30.0			20.3			19.7				11.2			10.2
		40.7			40.0			30.7			30.0				20.8			20.1
		50.7			50.0			41.0			40.2				30.8			30.1
	02	00.3			59.7			50.8			50.1				40.9			40.1
		10.4		45	09.7			59.9			59.2				51.2			50.4
		19.7			19.0		04	10.3		47	09.6			06	01.2		49	00.5
		30.5			29.9			20.2			19.5				11.0			10.2
		41.0			40.2			30.3			29.6				21.0			20.2
		50.8			50.1			41.1			40.2							
	03	00.4			59.8			51.3			50.6	Mean,	2	03	50.65	23	46	49.93

NOVEMBER 21, 1872.

Signals sent from Salt Lake.

Ft. Fred Steele chronometer.			Salt Lake chronometer.			Ft. Fred Steele chronometer.			Salt Lake chronometer.			Ft. Fred Steele chronometer.			Salt Lake chronometer.		
h.	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*		*h.*	*m.*	*s.*	*h.*	*m.*	*s.*
2	00	34.5	23	43	36.9	2	02	24.8	23	45	27.1		2	04	14.9	23	47	17.3
		44.2			46.8			34.6			37.0				25.1			27.7
		54.1			56.7			44.4			46.9				34.9			37.3
	01	04.2		44	06.8			54.5			56.9				44.7			47.1
		14.5			17.0		03	04.5		46	07.0				54.7			57.1
		24.6			27.1			14.8			17.1			05	04.9		48	07.4
		34.4			36.9			25.1			27.6				15.1			17.6
		44.3			46.8			34.6			37.1				25.3			27.8
		54.3			56.8			44.6			47.1				35.1			37.8
	02	04.3		45	06.8			54.6			57.0							
		14.6			17.0		04	04.8		47	07.1	Mean,	2	03	04.65	23	46	07.12

Signals sent from Fort Fred Steele.

Ft. Fred Steele chronometer.			Salt Lake chronometer.			Ft. Fred Steele chronometer.			Salt Lake chronometer.			Ft. Fred Steele chronometer.			Salt Lake chronometer.		
h.	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*		*h.*	*m.*	*s.*	*h.*	*m.*	*s.*
2	06	45.2	23	49	47.8	2	08	55.5	23	51	58.1		2	11	05.9	23	54	08.5
		56.6			59.2		09	05.8		52	08.3				15.1			17.5
	07	05.1		50	07.6			....			....				25.6			28.1
		14.9			17.5			....			....				35.0			37.5
		25.2			27.5			34.9			37.5				45.7			48.2
		34.5			37.0			....			....				56.1			58.5
		45.4			48.0			....			....			12	06.2		55	08.5
		55.5			58.1		10	....		53	....				15.6			18.1
	08	05.6		51	08.1			....			....				25.5			28.1
		....			....			....			....				35.0			37.6
		....			....			34.8			37.3				45.7			48.2
		34.4			37.0			45.5			48.0							
		45.2			47.5			55.9			58.3	Mean,	2	09	49.69	23	52	52.20

NOVEMBER 22, 1872.

Signals sent from Salt Lake.

Ft. Fred Steele chronometer.			Salt Lake chronometer.			Ft. Fred Steele chronometer.			Salt Lake chronometer.			Ft. Fred Steele chronometer.			Salt Lake chronometer.		
h.	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*		*h.*	*m.*	*s.*	*h.*	*m.*	*s.*
1	57	23.1	23	40	27.1	1	59	13.1	23	42	17.1		2	01	03.3	23	44	07.2
		33.0			37.0			23.1			27.1				13.5			17.3
		42.9			46.9			33.0			36.9				23.4			27.2
		53.1			57.1			43.0			46.9				33.3			37.1
	58	02.6		41	06.6			53.0			56.9				43.3			47.2
		12.9			16.9	2	00	03.1		43	07.1				53.1			57.1
		22.9			26.9			13.1			17.1			02	03.4		45	07.2
		32.8			36.8			23.1			27.1				13.7			17.7
		42.9			46.9			33.0			37.0				23.6			27.4
		52.8			56.8			43.1			47.0							
	59	03.0		42	06.9			53.1			57.0	Mean,	1	59	53.11	23	42	57.05

Signals sent from Fort Fred Steele.

Ft. Fred Steele chronometer.			Salt Lake chronometer.			Ft. Fred Steele chronometer.			Salt Lake chronometer.			Ft. Fred Steele chronometer.			Salt Lake chronometer.		
h.	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*		*h.*	*m.*	*s.*	*h.*	*m.*	*s.*
2	12	00.1	23	55	04.1	2	13	50.6	23	56	54.7		2	15	40.4	23	58	44.3
		10.8			14.9		14	00.3		57	04.3				50.9			54.9
		20.8			24.9			10.8			14.9			16	00.6		59	04.5
		31.0			35.0			20.7			24.8				10.9			14.8
		40.3			44.2			30.7			34.7				20.8			24.9
		50.6			54.7			40.4			44.3				30.9			34.9
	13	00.0		56	04.0			50.9			54.9				40.5			44.6
		10.3			14.2		15	00.9		58	04.9				51.0			55.0
		20.6			24.7			10.5			14.3			17	01.0	24	00	05.0
		31.0			35.0			20.6			24.8							
		40.4			44.3			30.9			34.9	Mean,	2	14	30.65	23	57	34.66

NOVEMBER 25, 1872.

Signals sent from Salt Lake.

Ft. Fred Steele chronometer.			Salt Lake chronometer.			Ft. Fred Steele chronometer.			Salt Lake chronometer.			Ft. Fred Steele chronometer.			Salt Lake chronometer.		
h.	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*		*h.*	*m.*	*s.*	*h.*	*m.*	*s.*
2	36	24.0	0	19	33.1	2	38	14.4	0	21	23.5		2	40	04.7	0	23	13.9
		34.3			43.3			24.2			33.3				14.7			23.9
		44.8			54.0			34.5			43.8				24.6			33.9
		54.5		20	03.8			45.0			54.2				34.9			44.0
	37	04.3			13.4			54.8		22	04.0				45.1			54.1
		14.2			23.3		39	04.6			13.9				55.0		24	04.2
		24.1			33.3			14.7			23.9			41	04.8			14.1
		34.3			43.5			24.3			33.3				14.8			24.0
		44.8			54.0			34.7			44.0				24.8			34.0
		54.7		21	04.0			44.8			54.1							
	38	04.4			13.6			54.8		23	04.1	Mean,	2	38	54.60	0	32	03.79

Signals sent from Fort Fred Steele.

Ft. Fred Steele chronometer.	Salt Lake chronometer.	Ft. Fred Steele chronometer.	Salt Lake chronometer.	Ft. Fred Steele chronometer.	Salt Lake chronometer
h. m. s.	h. m. s.	h. m. s.	h. m. s.	h. m. s.	h. m. s.
2 48 54.8	0 32 04.1	2 50 25.5	0 33 34.9	2 51 54.9	0 35 04.2
49 05.2	14.2	34.8	44.1	52 05.6	15.0
15.7	25.1	45.3	54.6	15.9	25.2
25.7	35.1	54.9	34 04.2	25.7	35.1
35.2	44.5	51 05.5	14.8	34.7	44.1
45.3	54.7	15.7	25.1	45.6	55.0
54.7	33 04.0	25.7	35.1	55.3	36 04.7
50 05.1	14.4	35.2	44.6		
15.7	25.1	45.4	54.9	Mean, 2 50 55.32	0 34 04.67

Signals sent from—	Recorded at—	Mean of signals sent and received.	Time corrections.	Corrected time.	Difference of longitude.	Double wave time.	Means.
Nov. 5, 1872.		h. m. s.	h. m. s.	h. m. s.	h. m. s.	s.	s.
Salt Lake	Ft. Fred Steele.	1 06 10.71	—2 00 22.69	23 05 48.02			
	Salt Lake.....	22 48 41.02	—0 02 40.76	22 46 00.26	0 19 47.76		
Fort Fred Steele	Ft. Fred Steele.	1 12 46.88	—2 00 22.67	23 12 24.21			
	Salt Lake.....	22 55 17.23	—0 02 40.76	22 52 36.47	47.74	0.02	47.750
Nov. 19, 1872.							
Salt Lake	Ft. Fred Steele.	2 02 58.30	—1 59 26.39	0 03 31.91			
	Salt Lake.....	23 45 56.97	—0 02 12.59	23 43 44.38	47.53		
Fort Fred Steele	Ft. Fred Steele.	2 10 03.11	—1 59 26.37	0 10 36.74			
	Salt Lake.....	23 53 01.84	—0 02 12.58	23 50 49.26	47.48	0.05	47.505
Nov. 20, 1872.							
Salt Lake	Ft. Fred Steele	1 57 47.71	—1 59 23.03	23 58 24.68			
	Salt Lake	23 40 46.93	—0 02 09.98	23 38 36.95	47.73		
Fort Fred Steele	Ft. Fred Steele.	2 03 50.65	—1 59 23.01	0 04 27.64			
	Salt Lake.....	23 46 49.93	—0 02 09.97	23 44 39.96	47.68	0.05	47.705
Nov. 21, 1872.							
Salt Lake	Ft. Fred Steele	2 03 04.65	—1 59 17.64	0 03 47.01			
	Salt Lake	23 46 07.12	—0 02 07.66	23 43 59.46	47.55		
Fort Fred Steele	Ft. Fred Steele.	2 09 49.69	—1 59 17.62	0 10 32.07			
	Salt Lake.....	23 52 52.20	—0 02 07.65	23 50 44.55	47.52	0.03	47.535
Nov. 22, 1872.							
Salt Lake	Ft. Fred Steele	1 59 53.11	—1 59 14.08	0 00 39.03			
	Salt Lake	23 42 57.05	—0 02 05.53	23 40 51.52	47.51		
Fort Fred Steele	Ft. Fred Steele.	2 14 30.65	—1 59 14.04	0 15 16.61			
	Salt Lake.....	23 57 34.66	—0 02 05.51	23 55 29.15	47.46	0.05	47.485
Nov. 25, 1872.							
Salt Lake	Ft. Fred Steele.	2 38 54.60	—1 59 01.83	0 39 52.77			
	Salt Lake	0 22 03.79	—0 01 58.80	0 20 04.99	47.78		
Fort Fred Steele	Ft. Fred Steele	2 50 55.32	—1 59 01.79	0 51 53.53			
	Salt Lake.....	0 34 04.67	—0 01 58.78	0 32 05.89	47.64	0.14	47.710

Final difference of longitude: Fort Fred Steele, east of Salt Lake, $0^h\ 19^m\ 47^s.612 \pm 0^s.034$.

Observations and computations for latitude of Fort Fred Steele, Wyo.

NOVEMBER 3, 1872.

Number of star.	Micrometer-readings.	Level. N.	Level. S.	Remarks.	Half sum of declination.	Corrections. Micrometer and reference.	Corrections. Level.	Corrections. Meridian.	Latitude.
	t. d.	*d.*	*d.*		° ′ ″	′ ″	″		° ′ ″
8212	4 1.5	9.5	32.5						
8247	26 32.2	36.0	6.0	.....	41 35 6.2	−11 33.3	+ 1.8	.....	41 46 41.3
8256	35 67.0	20.0	21.0						
8322	29 63.5	23.0	17.5	.....	49 47.4	− 3 7.6	+ 1.2	.....	41.0
8284	5 43.0	20.0	21.0						
8322	29 63.5	23.0	17.5	.....	34 6.3	+12 32.3	+ 2.9	.....	41.5
8330	26 82.0	23.0	17.5						
4	20 7.0	23.0	18.0	.....	43 11.3	+ 3 29.8	+ 2.9	.....	44.0
51	25 46.5	24.5	19.0						
58	12 23.5	28.5	14.0	.....	39 44.2	+ 6 51.2	+ 5.5	.....	40.9
101	2 43.3	19.5	20.0						
114	34 17.0	14.0	26.0	.....	30 15.0	+16 26.4	− 3.4	.....	38.0
gr.96	9 2.2				50 6.1	− 3 29.9	+ 2.0	.....	38.2
146	11 5.0	7.0	32.0	.....	49 3.7	− 2 26.8	+ 2.0	.....	38.9
153	26 75.6				40 56.5	+ 5 41.3	+ 2.0	.....	39.8
166	15 77.5	35.5	3.5						
215	36 99.5	25.5	13.5						
239	11 5.0	15.5	25.5	.....	60 5.8	−13 26.4	+ 0.6	.....	40.0
250	0 19.0	25.5	13.5						
253	34 10.0	15.0	27.5	.....	29 6.0	+17 33.9	− 0.1	.....	39.8
282	13 10.0	.....	.....	.....	39 59.5	+ 6 41.2	− 0.1	.....	40.6
299	10 83.2	24.5	19.0						
314	26 98.0	15.5	28.0	.....	38 21.1	+ 8 21.9	− 1.8	.....	41.2
330	12 58.0	20.5	22.0						
343	15 96.0	25.0	18.0	.....	48 23.5	− 1 45.1	+ 1.5	.....	39.9

NOVEMBER 4, 1872.

8024	6 48.0	28.0	23.0						
8082	21 53.0	8.0	44.0	.....	41 54 37.0	− 7 47.7	− 8.6	.....	41 46 40.7
8083	3 99.0	26.0	26.0						
8097	30 91.5	8.5	43.5	.....	60 46.7	−13 56.8	−11.4	.....	38.5
8212	4 96.0	24.0	27.0						
8223	22 13.0	9.0	43.0	.....	37 59.0	+ 8 53.6	−10.1	.....	42.5
8237	27 65.0	10.0	42.0	.....	35 6.3	+11 45.2	− 9.7	.....	41.8
8256	35 37.0	6.0	45.0						
8322	29 58.5	30.0	20.5	.....	49 47.5	− 2 59.8	− 8.1	.....	39.6
8330	26 82.4	30.0	20.5						
4	19 78.5	6.0	42.0	.....	43 11.4	+ 3 38.8	− 7.3	.....	42.9
153	25 68.0	19.0	33.0						
166	14 28.5	10.0	42.5	.....	40 56.7	+ 5 54.2	−12.7	.....	38.2
215	37 6.0	18.0	35.0						
239	11 37.5	18.0	35.0	.....	60 6.0	−13 18.3	− 9.3	.....	38.4
250	0 27.0	15.0	39.5						
282	13 30.2	17.0	40.0	.....	39 59.6	+ 6 51.3	−13.1	.....	37.8
299	9 71.0	28.0	28.0						
314	26 4.5	8.0	48.0	.....	38 21.3	+ 8 27.7	−11.0	.....	38.0
330	12 70.0	48.0	8.0						
343	15 68.0	....	....	(*)	48 23.7	− 1 32.6	−11.0	.....	40.1

* Level could not be read on reversal.

Observations and computations for latitude of Fort Fred Steele, Wyo.—Continued.

NOVEMBER 4, 1872.

Number of star.	Micrometer-readings.	Level. N.	Level. S.	Remarks.	Half sum of declination.	Corrections. Micrometer and reference.	Corrections. Level.	Corrections. Meridian.	Latitude.
	t. d.	d.	d.		° ′ ″	′ ″	″		° ′ ″
409	15 86.0	....	....						
441	24 98.0	....	....	.....	41 42 6.5	— 4 43.5	—11.0	.....	41 46 39.0
480	12 15.5	14.0	40.0						
501	20 7.0	19.0	35.0	.....	42 45.4	+ 4 6.0	—11.5	.....	39.9
558	24 68.0	14.0	42.0						
569	38 78.5	....	....		44 18.4	+ 2 32.0	—11.0	.....	39.7
610	22 54.0	....	....		39 10.3	+ 7 43.7	—10.5	.....	43.5
620	10 70.2	11.0	44.0	.....	54 8.1	— 7 14.1	—10.4	.....	43.6
686	7 62.0	25.0	30.0						
707	24 67.0								
731	11 99.0	38.0	18.0						
786	12 2.0	0.0	56.0	.....	46 50.9	— 0 0.9	— 9.9	.....	40.1

NOVEMBER 6, 1872.

7623	17 46.7	30.0	32.0						
7636	2 70.5	11.0	51.0	.....	41 54 32.0	— 7 38.8	—11.5	.....	41 46 41.7
7699	17 50.2	16.0	47.0						
7712	19 58.0	48.0	15.5	.....	47 43.3	— 1 4.6	+ 0.4	.....	39.1
7754	12 67.2	30.5	31.5	.....	57 6.0	—10 26.9	+ 1.2	.....	40.3
7778	0 94.5	....	....	.....	63 10.5	—16 31.5	+ 1.2	.....	40.2
7798	22 84.0	33.5	28.0	Must be 32†					
7815	18 74.2	....	....	(†)					
7843	16 74.8	....	....	.....	45 36.0	+ 1 2.0	+ 1.2	.....	39.2
7880	16 61.2	21.0	40.0						
7894	19 64.0	35.0	26.0	.....	45 8.4	+ 1 34.1	— 2.7	.....	39.8
7962	28 31.8	29.0	34.0	(;)	57 40.5	—10 50.4	—10.4	.....	39.7
7972	7 39.0	15.0	48.0	.....	47 1.5	— 0 21.1	— 2.0	.....	38.4
7994	8 7.0	45.0	19.0						
8024	6 75.8	35.5	28.0	.....	54 10.8	— 7 27.5	— 3.4	.....	39.9
8083	4 22.0	34.5	29.0	.....	60 46.9	—14 5.1	— 4.0	.....	37.8
8091	21 15.5								
8097	31 41.0	22.0	42.0						
8212	4 89.7	33.0	29.0						
8237	27 45.0	17.0	45.0	.....	35 6.5	+11 41.0	— 6.6	.....	40.9
				Releveled.					
8256	36 35.2	31.5	31.5	.....	51 15.9	— 4 29.7	— 6.6	.....	39.6
8284	6 13.5	23.0	39.0	.....	34 6.7	+12 36.0	— 4.4	.....	38.3
8322	30 46.0	....	....	.....	49 47.7	+ 6 59.0	— 4.4	.....	42.3
8330	27 67.5	23.0	40.0						
4	20 95.7	42.0	20.0	.....	43 11.6	+ 3 28.8	+ 1.3	.....	41.7
51	25 54.2	32.0	31.0						
58	12 57.2	51.0	12.0	.....	39 44.5	+ 6 43.1	+12.6	.....	40.2
101	2 41.0	28.0	35.5						
114	33 80.0	57.5	6.0	.....	30 15.5	+16 15.6	+12.1	.....	43.2
146	9 83.8	....	....	.....	49 4.1	— 2 24.0	— 0.2	.....	39.9
153	25 50.3	31.0	31.0	.....	40 57.0	+ 5 42.9	— 0.3	.....	39.6
166	14 47.0	31.0	32.0						
215	36 61.0	35.0	27.5						
239	10 62.0	27.5	36.0	.....	60 6.3	—13 27.8	— 0.3	.....	38.2
253	33 65.2	30.0	33.5	.....	48 10.6	— 1 31.9	+ 1.1	.....	39.8
282	12 58.8	35.0	27.5	.....	59 3.8	—12 26.6	+ 4.1	.....	41.3

† No level taken. ; Level doubtful.

Observations and computations for latitude of Fort Fred Steele, Wyo.—Continued.

NOVEMBER 6, 1872.

Number of star.	Micrometer-readings.	Level. N.	Level. S.	Remarks.	Half sum of declination.	Corrections. Micrometer and reference.	Corrections. Level.	Corrections. Meridian.	Latitude.
	t. d.	d.	d.		° ′ ″	′ ″	″		° ′ ″
299	10 43.0	29.0	35.0						
314	26 30.0	48.0	16.0	.....	41 38 21.6	+ 8 13.2	+ 7.1	.....	41 46 41.9
330	12 32.5	36.0	27.5						
343	15 87.0	37.0	27.0	.....	48 24.0	− 1 50.2	+ 5.1	.....	38.9
409	16 9.8	38.0	25.0						
441	24 66.2	38.5	24.5	.....	42 6.8	+ 4 26.2	+ 7.4	.....	40.4
480	13 65.0	25.0	36.5						
501	20 98.5	50.5	11.0	.....	42 45.8	+ 3 48.0	+ 7.7	.....	41.5
558	24 39.0	46.0	17.5						
569	19 93.0	23.5	40.0	Cloudy....	44 19.1	+ 2 18.6	+ 3.3	.....	41.0

NOVEMBER 8, 1872.

8212	3 65.0	23.5	23.0		41 37 59.4	+ 8 33.5	+ 9.4	.....	41 46 42.3
8223	20 17.3	40.0	6.0						
8257	25 74.7	....	....	.....	35 6.7	+11 26.8	+ 9.4	.....	42.9
8256	35 85.5	26.0	19.5		49 47.8	− 3 12.0	+ 5.4	.....	41.2
8284	5 52.0	....	....		34 6.9	+12 28.9	+ 5.4	.....	41.2
8322	29 67.7	29.0	16.0						
8330	26 88.0	29.0	16.0						
4	20 40.0	32.0	14.0	.....	43 11.8	+ 3 21.4	+ 8.6	.....	41.8
51	24 86.0	24.0	22.0						
58	11 87.0	41.0	4.0	.....	39 45.0	+ 6 43.7	+10.7	.....	39.4
101	1 77.0	19.0	27.0						
114	33 37.0	32.0	13.0	.....	30 15.8	+16 22.1	+ 3.0	.....	40.9
Gr.96	8 57.8	29.0	16.5		50 6.9	− 3 33.3	+ 5.7	.....	39.3
146	10 59.0	....	....		49 4.4	− 2 30.7	+ 5.7	.....	39.4
153	26 26.0	....	....		40 57.4	+ 5 36.2	+ 5.7	.....	39.3
166	15 44.0	27.0	18.5						
215	37 46.0	16.0	30.0						
239	11 30.0	39.0	7.0	.....	60 6.6	−13 33.0	+ 4.9	.....	38.5
250	0 63.6	17.0	28.5						
253	34 29.0	40.0	6.0		29 6.9	+17 26.2	+ 6.2	.....	39.3
282	13 35.6	....	....		40 0.4	+ 6 35.5	+ 6.2	.....	42.1
299	7 94.5	21.0	25.0						
314	24 11.5	18.0	28.0	(*)	38 21.9	+ 8 22.6	− 3.8	.....	40.7
330	12 27.0	30.0	15.0						
343	15 93.5	34.0	12.0	.....	48 24.5	− 1 53.9	+10.1	.....	40.7
409	16 5.0	29.0	18.0						
441	24 48.0	42.0	5.0	.....	42 7.2	+ 4 22.0	+13.2	.....	42.4
480	12 3.0	13.5	33.5						
501	19 42.5	44.5	2.5	.....	42 46.1	+ 3 49.8	+ 6.0	.....	41.9
558	23 81.0	25.0	22.0						
569	19 51.0	32.5	14.0	.....	44 19.5	+ 2 13.6	+ 5.9	.....	39.0
588	38 76.5	....	....		27 5.7	+19 26.4	+ 7.7	.....	39.8
610	22 32.3	27.0	19.0	....	39 11.0	+ 7 22.5	+ 7.7	.....	41.2
665	1 23.7								
686	8 2.5	34.0	14.0						
915	41 49.0	38.0	9.0						
962	27 18.2	22.0	25.0	....	53 58.1	− 7 24.7	+ 6.2	.....	39.6

* Level doubtful.

Observations and computations for latitude of Fort Fred Steele, Wyo.—Continued.

NOVEMBER 8, 1872.

Number of star.	Micrometer-readings.	Level. N.	Level. S.	Remarks.	Half sum of declination.	Corrections. Micrometer and reference.	Corrections. Level.	Corrections. Meridian.	Latitude.
	t. d.	d.	d.		° ′ ″	′ ″	″		° ′ ″
1007	14 97.2	27.0	19.0		41 45 20.1	+ 1 10.2	+ 8.5	.....	41 46 38.8
1011	22 25.7	....	....		41 33.3	+ 4 56.6	+ 8.5	.....	39.4
1017	12 71.5	35.0	11.5						
1052	24 51.0	19.0	28.0						
1058	11 88.8	46.0	0.0	....	53 2.7	— 6 32.3	+10.1	.....	40.5
1111	23 84.8	25.0	22.0		39 51.2	+ 6 38.1	+11.0	.....	40.3
1133	15 80.8	....	....		44 0.9	+ 2 28.2	+11.0	.....	40.1
1143	11 4.0	42.0	5.0						
1252	4 77.0	28.0	18.5						
1268	29 0.5	31.0	16.0	....	59 6.9	—12 33.2	+ 6.7	.....	40.4
1320	14 88.5	40.0	7.5						
1339	10 53.0	18.0	28.0	....	48 50.5	— 2 15.4	+ 6.2	.....	41.3
1397	12 41.0	....	....		52 52.5	— 6 20.1	+ 8.8	.....	41.2
1398	10 62.5	20.0	27.0		53 45.2	— 7 15.6	+ 8.8	.....	38.4
1414	24 64.0	43.0	4.0						

NOVEMBER 10, 1872.

8212	3 76.0	8.0	40.0						
8223	20 47.0	42.0	6.0		41 37 59.5	+ 8 39.3	+ 1.1	.....	41 46 40.0
8237	26 2.0	....	....	....	35 7.0	+11 31.8	+ 1.1	.....	39.9
8330	26 44.0	16.0	42.0						
8374	15 75.5	....	....		41 8.6	+ 5 32.1	0.0	.....	40.7
4	19 71.0	42.0	16.0	....	43 12.0	+ 3 29.2	0.0	.....	41.2
146	9 53.7	33.0	23.0						
166	14 42.0	42.0	14.0	....	49 4.7	— 2 31.8	+10.4	.....	43.3
299	8 23.7	18.0	40.0						
314	24 54.0	22.0	35.0	....	38 22.3	+ 8 26.7	— 9.9	.....	39.1
480	12 44 0	28.0	29.0	....					
501	20 33.5	15.0	42.0	Cloudy...	42 46.6	+ 4 2.3	— 7.7	.....	41.2

NOVEMBER 12, 1873.

7778	2 35.0	25.0	26.0						
7798	34 47.7	42.0	10.0	....	41 63 10.3	—16 38.5	+ 8.6	.....	41 46 40.4
7815	16 82.2	31.0	20.0						
7843	17 6.0	38.0	12.0	....	45 36.2	+ 0 54.8	+10.1	.....	41.1
7880	16 86.2	23.0	24.5						
7894	19 80.0	29.0	18.5	....	45 8.5	+ 1 31.3	+ 2.4	.....	42.2
7962	28 50.5	31.0	28.0	....	57 41.0	—11 9.3	+ 6.1	.....	37.8
7972	6 97.0	40.0	21.0						
7994	8 5.0	39.0	24.0	....	47 1.9	— 0 33.5	+ 8.3	.....	36.7
8024	6 71.5	32.0	30.0						
8032	22 33.5	45.0	20.0	....	54 37.7	— 8 5.5	+ 7.4	.....	39.6
8212	4 87.0	33.0	30.0						
8223	21 66.0	.....	.....	....	37 59.8	+ 8 41.8	— 1.8	.....	39.8
8237	27 24.5	27.0	36.5	....	35 7.2	+11 35.4	— 1.7	.....	40.9
8256	36 46.5	.....	.....	....	49 48.2	— 3 23.1	+16.0	.....	41.1
8284	6 18.0	.....	.....	....	34 7.2	+12 18.1	+16.0	.....	41.3
8322	29 93.0	34.0	29.0						
8330	27 10.0	.....	.....						
8374	16 86.0	58.0	5.0	....	41 8.7	+ 5 18.3	+ 16.0	.....	43.0

Observations and computations for latitude of Fort Fred Steele, Wyo.—Continued.

NOVEMBER 12, 1872.

Number of star.	Micrometer-readings.	Level. N.	Level. S.	Remarks.	Half sum of declination.	Corrections. Micrometer and reference.	Corrections. Level.	Corrections. Meridian.	Latitude.
	t. *d.*	*d.*	*d.*		° ′ ″	′ ″	″		° ′ ″
51	25 82.3	34.5	30.0						
58	12 81.0	44.0	21.0		41 39 45.4	+ 6 44.4	+ 7.7		41 46 37.5
101	3 95.0	38.0	27.0						
114	35 29.0	49.0	16.5		30 16.4	+16 14.0	+ 12.0		42.4
146	10 64.3				49 5.0	− 2 39.2	+14.3		40.1
153	26 30.3	35.0	27.0		40 57.4	+ 5 27.5	+14.3		39.2
166	15 76.5	53.0	9.0						
215	36 80.7	25.5	30.0						
239	10 80.0	42.0	14.0		60 7.3	−13 34.5	+6.4		39.2
250	0 2.0	24.5	33.0	50*s.* late.					
282	12 66.5	42.0	16.0		40 1.0	+ 6 33.0	+ 4.8	+ 0.2	39.0
299	9 97.0	20.0	27.0						
314	25 93.0	38.0	19.0		38 22.6	+ 8 16.0	+ 3.3		41.9
330	13 42.0	31.0	25.5						
343	16 90.5	32.0	25.0		48 25.1	−1 48.3	+ 3.4		40.2
409	17 17.5	35.5	20.0						
441	25 70.0	37.5	20.0		42 7.9	+4 25.0	+ 8.2		41.1
480	12 68.0	28.0	31.0						
501	20 17.0	33.5	25.0		42 46.9	+ 3 52.8	+ 1.5		41.2
558	24 7.0	33.5	26.5						
569	20 4.0	50.0	10.0		44 20.2	+ 2 5.3	+13.2		38.7
610	23 8.0	39.0	20.0		39 11.8	+ 7 25.2	+ 4.6		41.6
620	11 14.2	29.0	31.0		54 9.4	− 7 35.4	+ 3.7		37.8
686	8 75.5	39.5	20.5						
707	25 79.3	27.0	33.5						
885	14 64.8	36.0	23.5						
904	21 32.0	43.0	17.0		49 58.3	− 3 27.4	+10.5		41.4
1007	15 77.0				45 20.7	+ 0 59.4	+18.1		38.2
1011	23 6.5	39.0	20.0		41 33.9	+ 4 46.1	+18.1		38.1
1017	13 86.0	53.0	6.0	Releveled.					
1052	23 73.2	25.0	33.0						
1058	11 74.0	10.0	*48.0		53 3.4	− 6 12.7	−12 6		38.1

NOVEMBER 18, 1872.

8330	25 96.2	36.0	8.0						
4	19 59.5	31.0	†16.0		41 43 13.0	+ 3 17.9	+11.9		41 46 42.8

NOVEMBER 21, 1872.

857	21 44.8				41 37 10.8	+ 9 37.1	− 7.1		41 46 40 8
858	18 48.5	33.0	25.0		38 42.1	+ 8 5.0	− 7.1		40.0
872	2 88.0	12.0	46.0						
885	14 35.5	29.0	27.5						
904	20 60.0	18.0	40.0	Cloudy . .	49 59.9	− 3 14.1	− 5.6		40.2

* Observer became sick. † Clouds prevented further observations.

Observations and computations for latitude of Fort Fred Steele, Wyo.—Continued.

NOVEMBER 24, 1872.

Number of star.	Micrometer-readings.	Level.		Remarks.	Half sum of declination.	Corrections.			Latitude.
		N.	S.			Micrometer and reference.	Level.	Meridian.	
	t. d.				° ′ ″	′ ″	″		° ′ ″
7623	17 73.5	16.0	37.0						
7631	26 62.0	32.5	20.0	....	41 42 7.2	+ 4 36.1	− 2.3	.....	41 46 41.0
7699	17 11.8	26.5	24.0						
7712	19 20.5	24.0	26.0	....	47 43.3	− 1 4.9	+ 0.1	.....	38.5
7754	12 28.0	.....	.....	....	57 6.2	−10 33.6	+ 8.8	.....	41.4
7778	0 52.0	22.0	28.0	....	63 10.4	−16 39.1	+ 8.8	.....	40.1
7798	32 66.7	45.0	7.0						
7962	27 89.5	28.0	18.0						
7972	6 91.0	3.0	43.5	....	57 41.4	−10 52.2	− 8.8	.....	40.4
8024	5 98.0	29.5	17.0	....	54 12.1	− 7 45.1	+ 13.1	.....	40.1
8083	3 71.0	16.0	33.5	....	60 48.2	−14 11.9	+ 4.8	.....	41.1
8091	20 94.5	42.0	7.0						
8097	31 12.0	.....	.....						
8284	5 87.0	5.0	35.5						
8322	30 18.0	28.0	16.0	....	34 8.7	+ 12 35.6	− 5.1	.....	39.2
8330	27 37.3	28.0	16.0						
8374	16 87.5	23.0	21.0	....	+41 10.2	+ 5 26.3	+ 3.6	.....	40.1
4	20 82.2	.....	.....	....	43 13.7	+ 3 23.6	+ 3.6	.....	40.9
146	10 4.0	28.5	11.5	....	49 6.6	− 2 34.5	+ 9.5	.....	41.6
153	25 75.0	.....	.....	....	40 59.0	+ 5 33.7	+ 9.5	.....	42.2
166	15 1.2	29.0	11.5						
299	10 55.0	18.5	27.0						
314	26 23.0	48.0	− 3.0	....	38 24.3	+ 8 7.3	+ 10.1	.....	41.7
330	13 49.0	33.0	12.5						
343	17 18.5	27.0	18.0	....	48 26.9	− 1 54.8	+ 8.1	.....	40.2
409	17 40.5	30.0	16.0	....	48 32.7	− 1 1.7	+ 9.4	.....	40.4
558	24 23.0	25.0	21.5						
569	20 13.0	42.5	4.0	....	44 22.1	+ 2 7.4	+ 11.5	.....	41 0
610	23 10.0	24.0	33.0						
636	8 71.2	23.0	25.5	30 s. late ..	39 13.6	+ 7 27.2	− 3.2	− 0.1	37.7
757	16 40.8	.....	.....	....	49 58.1	− 3 9.5	− 7.0	.....	41 6
759	31 38.0	30.5	18.0	....	57 42.4	−10 54.9	− 7.0	.....	40.5
816	10 31.0	5.0	43.0						
831	27 83.0	13.5	32.5						
857	21 14.0	42.0	3.0	....	50 4.6	− 3 27.9	5.5	.....	42.2
858	18 23.0	42.0	3.0						
872	2 91.0	7.0	36.5	....	38 42.6	+ 7 56.1	+ 2.6	.....	41.3
915	25 51.5	16.0	25.0						
962	11 22.2	37.0	5.0	....	54 1.0	− 7 24.2	− 6.3	.....	43.1
1007	20 3.6	25.0	17.0	....	45 22.9	+ 1 2.3	+ 13.7	.....	38.9
1011	27 35.0	.....	.....	....	41 36.1	+ 4 49.7	+ 13.7	.....	39.5
1017	18 3.0	47.0	− 5.0						
1052	24 2.5	30.0	27.0	....					
1058	11 83.5	17.0	40.0	... .	53 5.5	− 6 18.9	− 5.5	.....	41 1
1111	24 82.0	31.0	26.0						
1143	11 72.0	30.5	26.0	....	39 53.7	+ 6 47.1	+ 2.6	.....	43.4
1305	28 7.5	26.0	33.0						
1320	15 24.0	52.0	7.0	....	39 48.9	+ 6 38.9	+ 10.4	.....	38.2
1397	16 41.0	.....	.....	....	52 54.4	− 6 13.6	− 1.5	.....	39.3
1398	14 70.0	30.5	32.0	....	53 47.6	− 7 6.7	− 1.5	.....	39.4
1414	28 43.0	29.0	33.0						
1527	30 88.0	30.0	31.0						
1536	5 24.5	15.0	46.0	Cloudy ...	60 3.6	−13 16.7	− 8.8	.....	38.1

Observations and computations for latitude of Fort Fred Steele, Wyo.—Continued.

NOVEMBER 26, 1872.

Number of star.	Micrometer-readings.	Level. N.	Level. S.	Remarks.	Half sum of declination.	Corrections. Micrometer and reference.	Corrections. Level.	Corrections. Meridian.	Latitude.
					° ′ ″	′ ″	″		° ′ ″
480	12 76.5	27.0	33.0						
501	20 47.2	21.0	39.0	....	41 42 50.5	+ 3 59.5	− 6.6	.....	41 46 43.4
558	23 58.5	34.0	25.0						
569	19 70.3	52.0	7.0	....	44 22.4	+ 2 0.7	+14.9	.....	38.0
831	28 56.2	19.0	34.0						
858	19 26.8	22.5	31.0	....	51 36.3	− 4 48.9	− 6.4	.....	41.0
915	26 40.0	15.0	39.0						
962	12 24.0	37.0	18.0	....	54 1.3	− 7 20.1	− 1.3	.....	39.9
1007	19 39.0	28.0	25.0						
1017	17 38.0	48.0	5.0	....	45 23.2	+ 1 2.5	+12.6	.....	38.3
1052	24 50.8	24.0	30.0						
1058	12 23.0	18.0	36.0	....	53 5.8	− 6 21.6	− 6.6	.....	37.6
1111	24 85.8	28.0	26.0	... .	39 54.0	+ 6 32.5	+12.9	.....	39.4
1133	16 82.5	.....	.....	....	44 3.7	+ 2 22.8	+13.2	.....	39.7
1143	12 23.0	50.0	5.0						
1252	5 80.0	29.0	26.0						
1268	30 39.6	53.0	2.0	....	59 9.8	−12 44.4	+14.8	.....	40.2
1305	28 31.0	30.0	26.0	....	39 49.3	+ 6 37.5	+11.0	.....	37.8
1320	15 52.0	46.0	10.0						
1339	11 17.0	12.0	43.0	....	48 53.3	− 2 15.2	+ 1.3	.....	39.4
1397	16 37.2	.....	.....	....	52 54.7	− 6 13.5	− 2.9	.....	38.3
1398	14 64.0	29.5	25.0	....	53 47 9	− 7 7.3	− 2.9	.....	37.7
1414	28 39.0	20.0	35.0						

NOVEMBER 27, 1872.

7623	16 62.5	31.0	20.0						
7631	25 56.3	15.0	35.0	....	41 42 7.1	+ 4 37.8	− 2.4	.....	41 46 42.5
7699	16 54.0	19.5	26.5						
7712	18 72.0	35.0	10.0	....	47 43.5	− 1 7.8	+ 4.9	.....	40.6
7754	11 56.3	22.0	23.0						
7798	31 42.0	3.0	40.0	....	57 6.2	−10 17.1	−10.4	.....	38.7
7962	26 85.5	2.0	36.0						
7972	5 65.0	16.5	30 0	....	57 41.4	−10 59.0	− 3.7	.....	38.7
8024	4 67.5	19.0	29.0	....	54 12.3	− 7 41.9	+ 9.9	.....	40.3
8083	2 49.5	2.0	46.0	....	60 48.5	−14 10 1	+ 0.6	.....	39.0
8091	19 53.5	47.0	1.0						
8097	29 84.7								
8212	3 90.3	20.0	24.5						
8223	20 73.8	19.0	27.0	....	38 1.1	+ 8 43.2	− 3.4	.....	40.9
8237	26 28.0	.....	.....	....	35 8.5	+11 35.5	− 3.4	.....	40.6
8284	5 41.0	21.0	27.0						
8322	29 78.7	15.0	32.0	....	34 8.9	+12 37.6	− 6.3	.....	40.2
8330	26 98.0	15.0	32.0						
8374	16 40.0	35.0	12.0	....	41 9.9	+ 5 28.8	+ 1.7	.....	40.4
4	20 36.8	.....	.....	....	43.13.4	+ 3 25.5	+ 1.7	.....	40.6
51	24 75.5	24.5	25.0						
58	11 63.0	33.0	15.5	....	39 47.2	+ 6 47.9	+ 4.6	.....	39.7
146	10 64.0	26.0	21.0	....	49 6.9	− 2 39.4	+11.2	.....	38.7
153	26 31.0	.....	.....	....	40 59.9	+ 5 27.6	+ 4.2	.....	38.7
166	15 77.0	41.5	5.5						
215	37 43.3	22.0	24.5						
239	11 49.0	18.0	28.0	....	60 9.3	−13 26.3	− 3.4	.....	39.6

Observations and computations for latitude of Fort Fred Steele, Wyo.—Continued

NOVEMBER 27, 1872.

Number of star.	Micrometer readings.	Level. N.	Level. S.	Remarks.	Half-sum of declination.	Corrections. Micrometer and reference.	Corrections. Level.	Corrections. Meridian.	Latitude.
	t. d.	*d.*	*d.*		° ′ ″	′ ″	″		° ′
250	0 84.5	33.5	13.5						
282	13 56.8	18.0	28.0	....	41 40 2.9	+ 6 35.4	+ 2.7	.....	41 46 41
299	10 71.0	24.0	23.0						
314	26 80.0	17.0	30.0	....	38 24.7	+ 8 20.1	− 3.3	.....	41
330	12 12.0	31.0	16.0						
343	15 80.3	30.0	18.0	....	48 27.3	− 1 54.5	+ 7.4	.....	4
409	16 5.0	34.0	12.5						
441	24 64.0	21.0	25.5	....	42 10.1	+ 4 27.0	+ 4.6	.....	4
558	23 79.6	30.0	12.5						
569	19 26.3	10.0	33.0	....	44 22.7	+ 2 20.9	− 1.5	.....	4
757	15 0.5	.....	.....	....	49 58.4	− 3 10.7	− 6.6	.....	4
759	29 96.0	24.0	23.0	....	57 42.6	−10 55.5	− 6.6	.....	4
816	8 87.0	11.0	36.0						
857	21 59.0	.....	.....	....	37 11.7	+ 9 27.9	+ 1.5	.....	4
858	18 63.0	24.0	23.5	....	38 43.1	+ 7 55.9	+ 1.5	.....	4
872	3 31.7	27.0	22.0						
885	14 0.2	21.0	27.0						
904	20 66.5	44.0	4.0	....	50 0.8	− 3 27.1	+ 9.3	.....	
915	25 2.7	19.0	28.0						
962	10 84.6	28.5	18.0	....	54 1 5	− 7 20.7	+ 0.4	.....	
1007	19 94.0	22.0	26.0	Must be 18	45 23.3	+ 1 5.3	+10.4	.....	
1011	26 29.5	.....	.....	....	41 36.6	+ 4 53.9	+10.4	.....	
1017	16 84.0	45.0	3.0						
1052	24 96.0	22.0	25.0						
1058	12 55.0	24.0	23.0	....	53 5.9	− 6 25.7	− 0.5	.....	
1111	24 85.5	25.5	22.5	....	39 54.1	+ 6 33.8	+12.1	.....	
1133	16 81.3	.....	.....	....	44 3.9	+ 2 23.9	+12.1	.....	
1143	12 18.3	45.0	4.0						
1252	5 55.0	25.0	25.0						
1268	29 75.5	29.0	19.0	....	59 9.9	−12 32.3	+ 2.7	.....	
1305	27 61.5	28.0	20.0	....	39.49.5	+ 6 49.5	+ 1.8	.....	
1320	14 44.0	23.5	25.0						
1339	10 13.5	28.0	20.0	....	48 53.5	− 2 13.8	+ 1.8	.....	
1397	14 92.2	.....	.....	....	52 54.8	− 6 24.2	+ 9.9	.....	
1398	13 18.5	32.0	18.0	....	53 48.1	− 7 18.1	+ 9.9	.....	
1414	27 28.2	36.0	14.0						

Resulting astronomical co-ordinates.

The daily results, combining the observations of November 10, 18, 21, and 26, to one result, will b

	No. of obs.	° ′ ″
November 4	31	41 46 40.30
6	27	40.18
8	30	40.41
12	28	39.99
10, 18, 21, and 26	24	40.00
24	30	40.37
27	36	40.42

Giving every mean the same weight, the final result for the latitude of Fort Fred Steele will be:

Latitude..... 41° 46′ 40″.24 ± 0″.05

Longitude..... 7*h*. 7*m*. 47*s*.25 or 106 56 48 .80 west of Greenwic

1 59 35 .13 or 29 53 47 .00 west of Washing

LARAMIE.

Longitude—105° 35′ 33″.60 W.
Latitude—41° 18′ 51″.8 ± 0″.08 N.

At Laramie, a point in an open lot northeast from and near the railroad depot was selected as the station. It was not a desirable locality, but was about the only alternative by reason of the position of the telegraph wires. There was no possible objection to the position so far as the surface of the land was concerned, for the entire vicinity is but a gently undulating plain; but the observatory being in the middle of the city, the view both north and south was intercepted at short distances by houses, making it impossible to lay out any extended meridian line. Laramie stands centrally on the great plateau bearing the well-known name "Laramie Plains," and to my notion is the most inviting town on the whole transcontinental route. These plains, though some 7,000 feet above the level of the sea, are well clothed in grass, (but destitute of other forms of vegetation,) and watered by the Laramie River, which flows with a gentle current northerly through the valley. Mountains are visible to the right and left, and though from 8,000 to 10,000 feet high, appear only as slight ridges and low peaks from this elevated plateau.

Meteorological.—Two weeks of December were spent here, and the meteorological conditions experienced found to be very similar to those of the previous month at Fort Steele. The same violent dust and snow-storms prevailed, and though not quite so cold as it had been, it was not possible to run the observatory without a stove. Here, as at Fort Steele, there were times when it required the best exertion of the observers to keep the observatory and all its appliances from being blown away.

Observatory.—The observatory consisted of a hospital-tent—the same that was used at Cheyenne. The assistants were also the same. The operator was Mr. Williams, of the Western Union line.

Instruments.—Precisely the same as were used at Cheyenne and Fort Steele.

Connections.—Connection was made with Salt Lake by a loop into the main wire of the Western Union line. Some observations for latitude were made on each of the nights of December 6, 7, 8, 11, 13, 15, and 17. On the nights of the 9th, 12th, and 16th, observations for time were made and exchanged with Salt Lake for difference of longitude. Of all the stations occupied by Assistant J. H. Clark this has proven the least satisfactory, by reason of smoke and dust, and the near vicinity of moving trains.

Instrumental values.—See report on the Cheyenne station.

Table containing the corrections of chronometers and their rates.

LARAMIE.

Correction of Salt Lake chronometer.

1872.	Local sidereal time.	Correction of chronometer.	Adopted rate.
	h.	*h. m. s.*	*h.*
December 9	2.2	−0 1 34.73	0.115
December 12	1.0	26.41	0.115
December 16	1.0	−0 1 15.28	0.116

Correction of Laramie chronometer.

1872.	Local sidereal time.	Correction.	Adopted rate.
	s.	h. m. s.	s.
December 9	1.75	−1 53 11.56	−0.16
December 12	3.00	3.78	−0.16
December 16	3.00	−1 52 54.72	−0.04

Grouping of time signals and corrections and resulting longitudes.

Signals sent from—	Recorded at—	Mean of signals sent and received.	Time corrections.	Corrected time.	Difference of longitude.	Double wave time	Means.
		h. m. s.	h. m. s.	h. m. s.	h. m. s.		
Salt Lake	Salt Lake	2 32 19.90	−0 1 34.70	2 30 45.20			
	Laramie	4 49 9.25	−1 53 11.41	2 55 57.84	0 25 12.64		
Laramie	Salt Lake	2 39 13.57	−0 1 34.69	2 37 38.88			
	Laramie	4 56 2.93	−1 53 11.40	3 2 51.53	12.65		12.64
Salt Lake	Salt Lake	2 39 5.32	−0 1 26.23	2 37 39.09			
	Laramie	4 55 55.49	−1 53 3.78	3 2 51.71	12.62		
Laramie	Salt Lake	2 45 16.19	−0 1 26.21	2 43 49.98			
	Laramie	5 2 6.36	−1 53 3.76	3 9 2.60	12.62		12.62
Salt Lake	Salt Lake	3 6 39.93	−0 1 15.04	3 5 24.89			
	Laramie	5 23 32.19	−1 52 54.67	3 30 37.52	12.63		
Laramie	Salt Lake	3 13 3.74	−0 1 15.03	3 11 48.71			
	Laramie	5 29 55.95	−1 52 54.66	3 37 1.29	12.58		12.61

Final difference of longitude: Laramie, east of Salt Lake, $0^h\ 25^m\ 12^s.623 \pm 0^s.008$.

Observations and computations for latitude of Laramie, Wyo.

DECEMBER 6, 1872.

Number of star.	Micrometer-readings.	Level. N.	Level. S.	Remarks.	Half sum of declination.	Corrections. Micrometer and reference.	Corrections. Level.	Corrections. Meridian.	Latitude.
	t. d.	d.	d.		° ′ ″	′ ″	″		° ′ ″
8174	9 15.8	28.5	28.5						
8188	27 25.5	12.0	44.0		41 9 40.3	+ 9 22.4	− 8.8		41 18 53.9
8248	21 87.0	31.0	26.0						
8273	15 81.0	17.0	39.0		23 3.4	− 3 8.3	− 4.6		50.5
8279	22 54.0	34.0	23.0						
8296	13 97.5				14 19.1	+ 4 26.2	− 6.7		52.0
8301	18 52.5	34.5	21.0		16 29.0	+ 2 16.4	+ 6.7		52.1
68	19 12.0	31.0	23.0						
98	8 46.7	31.0	24.0		13 18.6	+ 5 31.1	− 4.1		53.*
116	9 25.0				13 43.1	+ 5 6.7	+ 4.1		53.9
146	34 28.5	25.0	31.0						
164	3 83.0	53.0	3.0		2 50.3	+15 46.5	+12.1		46.9
201	19 72.0	32.0	23.0						
224	16 0.5	49.5	5.0		16 41.8	+ 1 55.4	+14.7		51.9
250	18 32.7	29.0	25.0						
255	19 21.5	12.5	42.0		18 34.4	+ 0 27.6	− 7.0		55.0
339	20 92.0	32.0	23.0						
401	16 76.0	42.0	11.0		16 31.9	+ 2 9.3	+11.0		52.2
430	10 3.5	32.0	20.0						
450	26 8.2	15.0	37.0		10 35.0	+ 8 18.7	− 2.8		50.9
533	15 76.2	21.5	29.5						
564	23 66.2	*27.0	27.5		14 50.2	+ 4 5.4	− 3.7		51.9

* Must be 22'.0.

Observations and computations for latitude of Laramie, Wyo.—Continued.

DECEMBER 6, 1872.

Number of star.	Micrometer readings.	Level. N.	Level. S.	Remarks.	Half sum of declination.	Corrections. Micrometer and reference.	Corrections. Level.	Corrections. Meridian.	Latitude.
	t. d.	*d.*	*d.*		° ′ ″	′ ″	″		° ′ ″
666	20 93.2	27.5	24.5						
695	20 31.3	— 2.0	48.0	....	41 19 27.6	— 0 19.3	—12.9	.....	41 18 55.4
943	20 27.0	24.0	30.0						
980	20 7.0	52.0	2.0	....	18 30.4	+ 0 6.2	+12.1	.....	48.7
1017	10 79.0	30.0	25.0	30ˢ late ...					
1024	25 67.0	29.0	26.0	....	11 7.9	+ 7 42.5	+ 2.2	+0.1	52.7
1058	26 26.5	38.5	16.0	....	8 37.0	+10 7.3	+10.7	.....	55.0
1107	6 72.5	36.5	20.0						
1117	22 86.8	26.0	31.0	....	10 26.7	+ 8 21.7	+ 3.2	.....	51.6
1204	14 24.7	42.0	17.5						
1221	26 98.5	25.0	32.0	....	25 24.5	— 6 35.9	+ 4.8	.....	53.4

DECEMBER 7, 1872.

863	33 85.0	25.0	22.0						
872	3 30.5	8.5	39.5	40ˢ late ...	41 3 10.2	+15 49.3	— 7.7	—0.1	41 18 51.9
948	18 77.2	28.0	19.5						
980	18 28.5	30.0	20.0	....	18 30.6	+ 0 15.1	+ 5.1	.....	50.8
1017	11 72 0	29.0	20.0						
1024	26 90.0	.....	.....	....	11 8.1	+ 7 51.8	— 8.4	.....	51.5
1035	18 54.2	4.5	44.0	....	15 27.7	+ 3 32.0	— 8.4	.....	51.3
1058	86 91.0	18.5	31.0	....	8 37.1	+10 9.8	+ 7.5	.....	54.4
1107	7 29.0	44.5	5.0						
1133	30 73.0	24.0	23.0						
1140	6 38.0	32.5	13.0	....	6 9.6	+12 36.8	+ 5.6	.....	52.0
1204	12 82.0	27.5	20.0						
1221	25 81.5	39.0	7.5	....	25 24.4	— 6 43.9	+10.8	.....	51.3
1238	11 60.0	26.0	20.0						
1261	24 52.7	10.0	37.0	....	12 12.8	+ 6 41.8	— 5.7	.....	48.9
1286	13 75.2	26.0	23.0						
1316	23 49.0	21.5	26.0	....	23 54.7	— 5 2.7	— 0.4	.....	51 6
1382	27 44.5	28.0	19.0						
1408	9 85.3	14.0	30.0	....	9 46.9	+ 9 6.7	— 2.0	.....	51.6
1651	18 49.7	20.0	25.0						
1676	17 76.5	19.0	26.0	....	19 16.4	— 0 22.7	— 3.3	.....	50.4
1721	21 98.0	25.0	20.0						
1726	18 34.0	.....	.....	....	17 2.5	+ 1 53.1	— 3.3	.....	52.3
1734	15 45.5	15.0	32.0	....	15 32.0	+ 3 22.8	— 3.3	.....	51.5

DECEMBER 8, 1872.

7824	12 6.5	18.5	22.0						
7843	7 82.3	23.0	16.0	....	41 16 6.8	+ 2 42.9	+ 1.0	.....	41 18 50.7
7931	20 71.0	21.5	18.0						
7948	17 88.8	3.0	37.0	....	20 25.4	— 1 27.7	— 8.4	.....	49.3
7994	27 39.5	18.0	23.0						
8023	30 70.5	19.0	22.5	....	17 12.9	+ 1 42.9	— 2.3	.....	53.5
8079	19 98.0	42.0	10.0						
8083	20 1.0	0.0	52.0	....	18 58.2	+ 0 0.9	— 5.5	.....	53.6

Observations and computations for latitude of Laramie, Wyo.—Continued.

DECEMBER 8, 1872.

Number of star.	Micrometer-readings.	Level. N.	Level. S.	Remarks.	Half sum of declination.	Corrections. Micrometer and reference.	Corrections. Level.	Corrections. Meridian.	Latitude
	t. d.	*d.*	*d.*		° ′ ″	′ ″	″		° ′
8174	9 97.0	33.0	24.0						
8188	27 74.5	21.0	35.5		41 9 40.4	+ 9 12.5	− 1.5		41 18 51
8248	21 93.8	28.5	29.0						
8273	15 96.8	21.0	38.0		22 3.4	− 3 5.6	− 4.8		5
68	23 2.0	30.0	29.0						
98	12 24.8	29.0	32.0		13 18.7	+ 5 34.8	− 0.6		5
116	13 3.5				13 43.1	+ 5 10.3	− 0.6		5
146	34 49.0	23.0	37.5						
164	3 58.0	42.5	19.0		2 50 4	+16 0.7	+ 2.5		1
201	20 27.0	24.0	22.0						
224	16 25.0	28.0	18.0		16 41.9	+ 2 4.9	+ 3.3		1
290	22 81.0	31.0	14.0						
299	15 85.5	10.0	34.0		15 15.0	+ 3 36.2	− 2.0		
339	20 82.0	27.0	18.5						
401	16 42.6	19.5	26.0		16 32.1	+ 2 16.6	+ 0.6		
430	10 49.0	25.0	21.0						
450	26 95.5	0.0	47.0		10 35.0	+ 8 31.6	−11.9		
474	16 78.7	25.0	22.0		20 24.8	− 1 34.3	− 0.5		
487	21 90.0				17 44.9	+ 1 4.7	− 0.5		
516	19 82.0	21.0	26.0						
533	15 10.5	23.0	24.0						
535	12 52.0	14.5	33.0		20 17.4	− 1 20.3	− 5.4		
564	23 5.0	16.0	32.0		14 50.4	+ 4 6.3	− 5.4		
863	33 57.2	25.0	25.0						
872	3 39.0	33.0	18.0		3 10.4	+15 38.0	+ 4.1		
948	19 83.0	26.0	24.5						
980	19 17.0	28.0	22.0		18 30.7	+ 0 20.5	+ 2.1		
1107	6 92.0	30.5	20.0						
1117	22 99.9	35.5	16.0		10 26.5	+ 8 19.7	+ 8.1		
1133	31 21.5	31.0	18.5						
1140	6 99.4	31.0	17.5		6 9.8	+12 32.8	+ 7.2		
1204	13 34.5	29.0	20.0						
1121	25 93.0	22.0	26.5		25 24.5	− 6 31.1	+ 1.2		
1238	12 5.0	21.0	27.0						
1261	25 3.0	15.0	35.5		12 18.0	+ 6 43.4	− 7.3		
1382	27 80.5	33.0	19.5						
1408	10 70.0	37.0	14.0		9 49.5	+ 8 51.6	−10.0		

DECEMBER 11, 1872.

8317	15 25.5	22.0	24.0						
8337	32 1.0	10.5	35.0		27 39.8	− 8 40.8	− 7.3		
68	23 19.0	20.0	26.0						
98	12 4.0	4.0	42.0		13 18.9	+5 46.5	−12.1		
116	12 85.2				13 43.3	−5 21.3	−12.1		
122	11 96.2				13 15.8	+5 49.0	−12.1		
201	20 68.5	24.0	24.5						
224	16 35.2	15.0	32.0		16 42.1	+ 2 14.7	− 4.8		
250	19 24.2	26.0	20.0						
255	20 4.8	9.0	37.0		18 34.6	+ 0 25.6	− 6.0		

Observations and computations for latitude of Laramie, Wyo.—Continued.

DECEMBER 11, 1872.

Number of star.	Micrometer readings.	Level. N.	Level. S.	Remarks.	Half-sum of declination.	Corrections. Micrometer and reference.	Corrections. Level.	Corrections. Meridian.	Latitude.
	t. d.	d.	d.		° ′ ″	′ ″	″		° ′ ″
430	10 63.8	28.0	19.0						
450	26 86.0	4.0	43.0	....	41 10 35.3	+ 8 24.2	− 8.2	.....	41 18 51.3
474	16 22.0	15.0	30.0	....	20 25.0	− 1 41.3	+ 5.7	.....	49.4
487	21 37.0	.....	.....	....	17 45.2	+ 0 58.7	+ 5.7	.....	49.6
516	19 48.0	42.0	6.0						
533	15 90.5	25.0	23.0						
564	24 4.0	5.0	44.5	....	14 50.7	+ 4 12.8	−10.3	.....	53.2
698	27 9.0	28.0	22.0						
715	15 63.8	12.0	38.0	....	24 54.3	− 5 55.9	− 5.5	.....	52.9
735	7 78.0	.....	.....	....	28 26.5	− 9 29.0	− 5.5	.....	52.0
786	23 32.3	30.0	21.0						
827	12 31.0	0.0	51.0	....	24 44.7	− 5 42.3	−11.6	.....	50.8
863	33 96.0	28.0	23.5						
872	3 56.0	18.0	34.0	....	3 10.7	+15 44.8	− 3.2	.....	52.3
948	19 14.0	29.0	22.0						
980	18 79.0	42.0	7.0	....	18 31.2	+ 0 10.9	+11.6	.....	53.7
1017	12 2.0	20.0	26.0						
1024	26 72.6	.....	.....	....	11 8.6	+ 7 37.1	+ 5.2	.....	50.9
1035	18 36.2	35.0	10.0	....	15 28.3	+ 3 17.1	+ 5.2	.....	50.6
1058	25 96.5	22.0	24.0						
1007	6 56.8	45.0	2.0	.. ..	8 37.6	+10 2.9	+11.2	.....	51.7
1133	39 29.3	25.5	21.0						
1140	6 66.0	13.0	34.0	....	6 10.1	+12 45.6	−4.5	.....	51.2
1204	12 88.0	30.0	17.0						
1221	25 75.2	26.0	20.0	....	25 24.9	− 6 40.1	+ 5.2	.....	50.0
1238	11 65.0	18.0	26.0						
1261	24 46.0	20.0	25.0	....	12 18.4	+ 6 38.1	+ 3.5	.....	53.0

DECEMBER 13, 1872.

68	21 63.6	23 0	15.0						
98	10 86.5	.....	.....	....	41 13 19.0	+ 5 34.8	− 1.1	.....	41 18 52.7
116	11 66.7	13.0	25.0	....	13 43.3	+ 5 9.8	− 1.1	.....	52.0
122	10 78.3	.....	.....	....	13 15.9	+ 5 37.3	− 1.1	.....	52.1
201	19 44.8	31.0	26.0						
224	15 6.8	13.0	44.0	....	16 42.1	+ 2 16.1	− 7.2	.....	51.0
250	16 93.0	29.0	29.0						
255	18 56.0	28.0	30.0	Must be 17'	18 34.7	+ 0 19.6	− 0.6	.....	53.7
290	21 87.5	29.0	29.0						
299	15 17.8	42.0	17.0	....	15 15.5	+ 3 28.1	+ 6.8	.....	50 4
533	16 10.2	29.0	28.0						
564	24 10.5	17.0	40.0	....	14 50.8	+ 4 8.7	− 6.1	.....	53.4
620	32 54.5	27.0	27.0						
632	4 59.8	54.0	0.0	....	4 6.1	+14 28.6	+14.8	.....	49.5
657	18 98.3	.....	.....	....	19 30.5	− 0 33.3	− 5.7	.....	51.5
666	18 92.5	24.0	19.0	....	19 28.2	− 0 31.4	− 5.7	.....	51.1
695	17 91.3	18.0	34.0						
752	19 32.5	24.5	25.0						
785	18 51.8	42.0	9.0	....	19 10.2	− 0 25.1	+ 8.9	.....	54.0
948	18 61.0	31.0	23.0						
980	18 34.0	44.5	8.0	....	18 31.4	+ 0 8.4	+12.2	.....	52.0

Observations and computations for latitude of Laramie, Wyo.—Continued.

DECEMBER 13, 1872.

Number of star.	Micrometer readings.	Level. N.	Level. S.	Remarks.	Half-sum of declination.	Corrections. Micrometer and reference.	Corrections. Level.	Corrections. Meridian.	Latitude.
	t. d.	*d.*	*d.*		° ′ ″	′ ″	″		° ′ ″
1017	12 0.0	34.0	17.0						
1024	27 17.0	.....	.....	....	41 11 8.9	+ 7 51.5	− 8.2	.....	41 18 52.2
1035	18 76.0	2.0	49.0	....	15 28.5	+ 3 30.1	− 8.2	.....	50.4
1062	20 48 0	42.0	9.0						
1095	11 78.0	15.5	36.0	20ˢ late....	14 15.9	+ 4 30.4	+ 3.4	+ 0.1	49.8
1204	12 68.0	31.0	22.5						
1221	25 47.0	31.0	24.0	....	25 25.2	− 6 37.5	+ 4.3	.....	52.0
1238	11 38.0	25.0	31.0						
1261	23 81.8	45.0	11.5	....	12 18.7	+ 6 26.6	+ 7.6	.....	52.9

DECEMBER 15, 1872.

8079	19 21.5	17.0	28.5						
8083	18 86.0	33.0	13.0	....	41 18 58.0	− 0 10.4	+ 2.3	.....	41 18 49.9
8174	9 31.5	23.0	21.0						
8188	27 13.8	18.0	26.5	....	9 40.1	+ 9 13.9	− 1.8	.....	52.2
8248	21 16.2	20.0	24.0						
8273	14 85.0	30.5	14.0	....	22 3.4	− 3 16.2	+ 3.4	.....	50.6
8279	23 13.0	29.0	16.0						
8296	14 42.0	.....	.....	....	14 19.1	+ 4 30.7	+ 2.6	.....	52.4
8301	18 61.0	21.5	25.0	....	16 29.0	+ 2 20.5	+ 2.6	.....	52.1
8310	9 68.0	.....	.....	....	30 17.2	−11 30.4	+ 4.6	.....	51.4
8317	14 70.0	19.0	27.0	....	27 39.8	− 8 54.4	+ 4.6	.....	50.0
8337	31 89.5	36.0	11.0						
8345	37 56.0	33.5	12.5						
28	1 0.3	11.5	38.0	....	40 59 58.6	+18 56.2	− 1.5	.....	53.3
68	23 12.5	26.5	22.5						
98	12 37.0	.....	.....	....	41 13 19.1	+ 5 34.3	− 2.3	.....	51.1
116	13 18.8	19.0	31.5	....	13 43.3	+ 5 8.8	− 2.3	.....	49.8
122	12 28.5	.....	.....	....	13 15.9	+ 5 36.9	− 2.3	.....	50.5
201	20 4.5	28.0	22.5						
224	16 7.5	33.5	13.0	....	16 42.2	+ 2 3.4	+ 7.2	.....	52.8
250	17 61.0	21.5	25.0						
255	18 32.0	20.0	27.0	....	18 34.8	+ 0 22.1	− 2.9	.....	54.0
290	21 74.0	37.0	9.0						
299	15 10.2	29.0	15.0	....	15 15.5	+ 3 26.3	+11.6	.....	53.4
339	21 62.5	27.0	16.5						
401	17 45.3	35.5	7.5	....	16 32.5	+ 2 9.7	+10.6	.....	52.8
430	9 73.0	23.0	20.0						
450	25 81.0	12.5	30.5	....	10 35.7	+ 8 19.8	− 4.4	.....	51.1
474	15 93.5	.....	.....	....	20 25.4	− 1 36.7	+ 2.2	.....	50.9
487	21 13.5	28.5	14.0	....	17 45.5	+ 1 5.0	+ 2.0	.....	52.5
516	19 4.5	17.5	25.0						
533	15 35.0	19.0	23.0						
535	12 87.0	.....	.....	50ˢ late ...	20 18.0	− 1 17.1	− 9.5	+ 0.1	51.5
564	23 33.5	6.0	36.5	....	14 51.0	− 4 8.2	− 9.5	.....	49.7
576	24 36.0	.....	.....	....	29 26.4	−10 31.1	− 5.1	.....	50.2
580	33 5.2	20.0	23.0	....	33 10.9	−14 13.7	− 5.1	.....	52.1
579	31 52.0	.....	.....	....	33 58.0	−15 1.3	− 5.1	.....	51.6
587	4 5.3	14.0	29.5						
620	32 37.8	22.0	23.0						
632	4 20.0	37.0	8.5	....	4 6.2	+14 35.8	+ 7.6	.....	49.6

Observations and computations for latitude of Laramie, Wyo.—Continued.

DECEMBER 15, 1872.

Number of star.	Micrometer-readings.	Level. N.	Level. S.	Remarks.	Half sum of declination.	Corrections. Micrometer and reference.	Corrections. Level.	Corrections. Meridian.	Latitue.
					° ′ ″	′ ″	″		° ′ ″
657	19 17.8	.....	.....	....	41 19 30.7	— 0 35 2	— 4.3	.....	41 18 51.2
666	19 14.0	33.5	13.0	....	19 28.4	— 0 34.0	— 4.3	.....	50.1
695	18 4.5	5.0	41.0						
752	19 20.0	25.5	24.5						
785	18. 57.3	25.0	25.5	....	19 10.7	— 0 19.5	+ 0.1	.....	51.3
843	32 96.0	32.0	19.0						
872	2 69.0	18.5	32.0	....	3 11.0	+15 40.8	— 0.1	.....	51.7
948	19 42.0	25.5	25.0						
980	18 84.0	28.0	21.0	....	18 31.7	+ 0 18.0	+ 2.1	.....	51.8
1052	26 45.0	25.0	21.5	....	21 21.0	— 2 22.1	— 5.5	.....	53.4
1062	21 87.8	11.5	35.0						
1095	12 98.2	33.0	14.0	....	14 16.2	+ 4 36.5	— 1.2	.....	51.5
1107	6 70.0	22.0	24.5						
1117	23 3.0	15.5	31.5	....	10 27.8	+ 8 27.5	— 5.1	.....	50.2
1133	31 66.5	23.0	24.0						
1140	7 43.2	37.0	10.0	....	6 10.7	+12 33.2	+ 7.1	.....	51.0
1204	12 46.0	26.0	24.0						
1221	25 46.0	39.0	10.0	....	25 25.4	— 6 44.0	+ 8.8	.....	50.2
1238	12 31.0	25.5	23.0						
1261	25 11.0	16.5	32.0	....	12 18.9	+ 6 37.8	— 3.5	.....	53.2
1286	13 39.0	23.5	25.0						
1316	23 54.6	42.0	8.0	....	23 55.7	— 5 15.6	+ 8.9	.....	49.0
1382	27 20.3	30.0	18.5						
1408	10 10.3	35.0	13.0	....	9 50.5	+ 8 51.5	+ 9.2	.....	51.2
1546	12 80.4	36.0	7.5						
1572	31 0.0	24.0	24.5	....	28 11.3	— 9 25.5	+ 7.7	.....	53.5
1671	19 7.0	22.0	25.0						
1676	18 38.0	16.5	30.0	....	19 17.4	— 0 21.4	— 4.5	.....	51.5
1721	21 75.5	28.0	19.0						
1726	18 19.0	15.5	32.0	45° late ...	17 3.4	+ 1 50.8	— 2.1	+ 0.1	52.2

DECEMBER 17, 1872.

250	18 51.8	20.0	24.5						
255	19 29.5	15.0	29.5	....	41 18 34.9	+ 0 24.1	— 5.0	.....	40 18 53.5
290	22 38.0	24.5	20.0						
299	15 42.0	21.5	22.0	30° late ...	15 15.6	— 3 36.3	+ 1.1	+ 0.1	53.1
339	19 97.0	28.5	14.5						
401	15 93.8	37.5	7.0	....	16 32.6	+ 2 5.3	+12.2	.....	50.1
430	9 39.0	22.5	21.0						
450	25 30.0	23.0	20.0	....	10 35.8	+ 8 14.5	+ 1.2	.....	51.5
474	15 82.5	.....	.....	....	20 25.6	— 1 49.6	+13.2	.....	49.2
487	21 2.3	24.0	20.0	....	17 45.6	+ 0 52.0	+13.2	.....	50.8
516	19 35.0	44.0	0.0						
533	14 11.0	18.0	24.0						
564	21 78.0	28.5	13.0	....	14 51.7	+ 3 58.4	+ 2.6	.....	52.7
579	32 31.5	8.0	32.0						
587	4 82.0	20.0	20.0	....	33 11.1	—14 14.5	— 6.6	.....	50.0
620	32 9.2	17.0	24.0						
632	3 96.7	44.0	3.0	Must be —3°.0.	4 6.4	—14 34.1	+11.0	.....	51.5

Observations and computations for latitude of Laramie, Wyo.—Continued.

DECEMBER 17, 1872.

Number of star.	Micrometer-readings.	Level. N.	Level. S.	Remarks.	Half-sum of declination.	Corrections. Micrometer and refr.	Corrections. Level.	Corrections. Meridian.	Latitude.
	t. d.	*d.*	*d.*		° ′ ″	′ ″	″		° ′ ″
657	19 25.2	18.0	20.0	....	41 19 31.0	— 0 34.6	— 4.4	.....	41 18 52.0
666	19 16.0	....	....	....	19 28.7	— 0 31.7	— 4.4	.....	52.6
695	18 14.0	12.0	26.0	....					
752	18 41.0	16.5	25.0	....					
785	17 75.2	30.0	14.5	....	19 11.1	— 0 20.5	+ 1.9	.....	52.5
863	33 56.8	26.0	17.5	....					
872	3 14.2	10.0	32.5	35ˢ late ...	3 11.3	+15 45.6	— 3.8	+ 0.1	53.2
948	19 82.3	23.5	17.5	....					
980	19 38.0	33.0	6.0	....	18 32.0	+ 0 13.8	+ 9.0	.....	54.8
1017	11 49.0	18.0	21.0	....					
1024	26 52.0	....	....	....	11 9.3	+ 7 47.1	— 4.9	.....	51.5
1035	18 17.0	12.0	27.0	....	15 29.0	+ 3 27.6	— 4.9	.....	51.7
1052	25 40.0	18.5	21.0	....	21 21.4	— 2 31.4	+ 2.1	.....	52.1
1062	20 53.0	25.0	15.0	....					
1095	11 76.0	19.0	20.0	....	14 16.6	+ 4 32.6	+ 2.1	.....	51.3
1133	30 92.4	20.0	18.5	....					
1140	6 66.7	31.0	8.0	....	6 11.0	+12 33.9	+ 6.7	.....	51.6
1204	12 27.5	26.0	14.5	....					
1221	25 43.0	37.0	3.0	....	25 25.7	— 6 48.8	+12.5	.....	49.4
1238	11 6.8	16.0	22.0	....					
1261	23 90.5	13.0	25.0	....	12 19.2	+ 6 39.0	— 4.9	.....	53.3
1286	13 36.7	23.0	15.0	....					
1316	23 65.8	42.0	— 4.0	....	23 55.9	— 5 19.8	+14.8	.....	50.9

Resulting astronomical co-ordinates.

The following table contains the daily means for latitude:

1872.	No. of obs.	Mean latitude obtained. ° ′ ″
December 6	18	41 18 52.43
7	13	51.50
8	24	51.93
11	21	51.83
13	17	51.81
15	40	51.46
17	22	51.79

The mean of the daily results gives 51″.82; the mean of all observations made, 51″.78.

Adopted latitude ..... 41° 18′ 51″.80 ± 0″.08
Longitude ..... 7ʰ 2ᵐ 22ˢ.24 or 105° 35′ 33″.60 west of Greenwich.
1 54ᵐ 10ˢ.12 or 28° 32′ 31″.80 west of Washington

The following points are proposed for occupation as main astronomical stations during the field-season of 1874:

1. Las Vegas, N. Mex.
2. Cimarron, N. Mex.
3. Sidney Barracks, Neb.
4. Julesburgh, Neb.
5. Crossing of the Union Pacific Railroad by the one-hundredth meridian, or at the North Platte station, Nebraska.

The above will be sufficient during the coming year to answer all the wants experienced in checking belts of triangles to be extended over the area to be surveyed, and will continue the work upon the astronomical base.

The usual field-astronomical observations will be kept up, in accordance with the elaborated scheme of survey determined upon for the prosecution of further geographical work by the officers in executive charge of the several parties.

GEODETIC AND ASTRONOMICAL.

The character of the observations made in this most important branch of the survey has been improved and perfected so far as consistent with the policy of covering large geographical areas during a single field-season. The problem of conducting a geographical survey over mountainous areas by methods at once thorough and rapid presents many grave difficulties, prominent among which is the uncertainty as to the extent of the physical obstacles to be encountered. The present organization will, however, during the coming season prosecute its labors in accordance with a certain plan conditioned upon the character of the several portions of the area to be entered, and founded upon a comprehensive system of triangulation developed from bases whose extremities and azimuths are well determined, the former by astronomical methods. These series of triangles network the entire area; and in addition thereto the horizontal and vertical values of the drainage-lines of the several main and sub basins are determined.

The progress of the geodetic survey of the character proposed is somewhat slower than by the methods employed prior to the season of 1873; but when confined to areas of the public domain that are attracting attention on account of their mineral or other resources developing, and about to be developed, where the Indian tribes are quiet, the decrease in cost because of the smaller number of persons required in each party for reasons of safety makes apparent the fact that a well-established policy as to the character of the surveys over such areas may be reached. I have reason to believe that such a course is about to be adopted, and in consequence hereafter some of the parties of the survey, at least, may annually be sent to areas not occupied by hostile Indians; while other parties may be directed to more inaccessible portions of mountain-territory, where reconnoissance-work alone is required, and where escorts will be needed.

In the season of 1873, the astronomical co-ordinates of points, and the determination of meridional lines through them, were determined at Hughes', Colorado Springs, and Trindad, Col., and Fort Union, N. Mex., all on the eastern base of the Rocky Mountain range, and a series of triangles developed from bases at these points into portions of Colorado, New Mexico, Eastern Utah, and Eastern Arizona. The labors of the season of 1874 will take up the triangulation at the points where it was left in the preceding season, for the purpose of completing it over the area extending from the latitude of Denver southward to the thirty-second parallel. The several belts will be joined to a number of points, all of which are along nearly the same meridian east of the Rocky Mountain ridge. The bases are measured by compensated steel tapes, referred to a standard, and a sufficient number of repetitions made to guarantee a small probable error. The azimuths are also carefully determined.

At the extremities of the developed bases, angular measurements are taken to the most prominent points of the adjacent triangulation-belt, which points are natural objects—usually high mountain-peaks.

The extension of the triangulation is made from point to point in accordance with the plan made at the beginning of the season, and the azimuth of at least one side of every triangle determined.

Within the main or principal triangles there is measured a series of minor triangles, covering the entire mountain-area, checked latitudinally at specified points. The checks used for the remaining detailed operations of the survey are by latitudes along the meanders, and by the connection of station-points with three or more main or prominent points within the horizon of each. The belts of triangles are further controlled by interior check-bases at distances not exceeding one hundred and fifty miles from the primary astronomical point. By these methods, forty-four main triangulation-points were occupied in New Mexico and Arizona and thirty-six in Colorado during the season of 1873.

When the connection is made between the two sets, their publication will indicate the character of the results, which have so far proven very satisfactory, since the geographical position of most of the points used could not be sufficiently ascertained in advance to always insure certainty as to resulting well-conditioned triangles.

A part of the topographic work of 1873, especially that in Colorado, demands a representation upon a scale of one inch to four miles, because of the intricate character of the several drainage-lines within the Rocky Mountain system. This will in no wise interfere with the regular and systematic plan proposed for the atlas of the region west of the one hundredth meridian. Since the final publication of the same, may be made upon a scale of one inch to eight miles.

The remarkably fruitful results from the topographical work of the past season are a matter of much congratulation to me, since the several areas were widely distributed and the different points of departure comparatively remote. Certain of the topographical assistants, too, were inexperienced; yet, notwithstanding all this, and the multitude of physical obstacles constantly in the path of each one of the parties, the area covered has been notably large, and almost equal to that of the season of 1871, when it was principally by reconnoissance-methods that the results were obtained.

It has been alone due to the untiring vigilance of the officers in charge and the industry of the several topographical assistants that the material for the important contributions to the geography of so large a part of our western interior has been gathered.

METEOROLOGICAL BRANCH.

The general method of the previous seasons has been followed during that of 1873. Hourly observations have been taken at the primary astronomical stations with the cistern-barometer, psychrometer, and anemometer. As many cistern-barometers, aneroids, and psychrometers as could be used to advantage have been distributed among the different ent field-parties, and a system of observation has been so adapted to camps, triangulation, topographical, and other stations, as to insure the determination of the greatest possible number of altitudes. The record of all these observations, up to the close of the field-season of 1873, has been transcribed upon computation-sheets, corrected and reduced, and the computation of altitudes is going forward.

It is proposed to group these altitudes, in accordance with the main topographical features of the country, in tables, which will appear in volume 3 of the series of publications.

The contents of this volume will be—

1st. A synopsis of the general plan for meteorological observations, the methods of reduction and computation, and the application of the results.

2d. The tables of altitudes, with general description of the locality of each group.

3d. Contour-maps of the atlas-sheets, with the curves at such intervals of altitude as are warranted by the results in barometric hypsometry, in conjunction with the elevations and vertical distances determined by the topographers.

4th. Tables and plates deduced from the hourly observations at the astronomical stations. These will comprise the abnormal and horary oscillations, and the changes in temperature and humidity of the atmosphere, with their effect upon the mercurial column.

With these will be published all facts that have been observed concerning the climate and climatal oscillations, with a description of the physical geography of the region of territory surveyed.

This branch of the survey is indebted to the cordial co-operation of the United States Signal-Service.

It has not been practicable, with the limited force that could be employed in working up the meteorological observations, to prepare this matter for publication; but, as time can be spared from other branches, this will gradually be brought forward.

Being an auxiliary to the other branches of the survey, it is in all respects subordinate to, and most of its results incorporated with, them.

GEOLOGICAL BRANCH.

Four professional geologists have, for different periods, been employed to accompany the several geographical parties and examine the structure of the region traversed. Of these, Mr. G. K. Gilbert was engaged in 1871, and has continued with the survey up to the present time; Mr. A. R. Marvine was employed during a portion of the first year only; Mr. E. E. Howell during the second and third, and Prof. J. J. Stevenson during the third year.

In 1871, Mr. Gilbert traveled mostly with the main field-party, crossing portions of Nevada, California, and Arizona, and making the voyage of the Colorado. Mr. Marvine, who spent but two months at geological work, began his observations at St. George, Utah, and continued them, via Prescott, Camps Verde, and Apache, to Tucson, Ariz.

The succeeding year, Messrs. Gilbert and Howell were employed principally in Western and Southern Utah; but their examinations also reached into Eastern Nevada and Northern Arizona.

For the greater portion of the season Mr. Gilbert accompanied Lieutenant Hoxie, and Mr. Howell the main division; but, upon the return-march, Mr. Howell joined Lieutenant Hoxie's party, while Mr. Gilbert was detached, and traveled alone by way of the valley of the Sevier to the final rendezvous at Salt Lake City.

In 1873, Mr. Howell accompanied Lieutenant Hoxie throughout the season, spending the earlier portion of it in Southern Central Utah, and the latter in Western New Mexico; Mr. Gilbert traveling with divisions of the main party in New Mexico and Eastern Arizona, and Professor Stevenson with the party commanded by Lieutenant Marshall in Colorado.

In all cases the geologists were assigned to separate topographical parties, and their routes arranged, so as to give them opportunity to acquire the most comprehensive ideas of the character of the country, and to obtain the fullest collection of data in a little-known region.

To get a right understanding of the results of their work, it is necessary to appreciate a broad distinction that exists between two regions

of country that were entered. Almost the entire region included between "the Plains" and the Pacific Ocean is mountainous; that is, the rocks which are its foundation are bent and broken and uplifted into ridges, which ridges are mountain ranges. But there is one exceptional area in which the beds of rock lie level, or nearly so, and this was named by myself in the year 1871 the "Colorado Plateau" region. In its general features, it contrasts very strongly with the surrounding mountain country. It consists of a system of tables, in places rising above each other in step-like order, and elsewhere divided by narrow, deep, and often impassable gorges. A large portion of this region is drained by the Colorado and its tributaries, but other parts send their waters to the Sevier Desert and via the Rio Pecos to the Rio Grande.

Of the political divisions, it comprises portions of Utah, Colorado, Arizona, and New Mexico, and its physical boundaries are the Uintah Mountains at the north, the Rocky Mountains at the east, and at the west and south the regions of the Cordilleras.

Through the labors of the topographers and geologists, the general dimensions of this area are now for the first time known, and its western, southern, and southeastern boundaries, making a line 900 miles long, are drawn on the map.

Within it are exceptional opportunities for the study of certain special geological subjects, and to these their attention has been turned. One of them is that of erosion by running water, which finds its superlative expression in the cañons of the Colorado, and is there contrasted with erosion by rain and compared with erosion by drifting sand.

Another subject is that of the origin of mountains; for, although the plateaus are distinctively not mountains, they contain certain simple dislocations which are the germs of mountains, and bear the same relation to dynamical geology that embryos bear to biology. These dislocations are faults and simple folds, and they have been traced and studied for hundreds of miles.

Another subject to which great attention has perforce been given is that of volcanic phenomena.

Every State and Territory west of the plains, every physical division the Rocky Mountains, the Plateaux, the Cordilleras, are crowded with the products of volcanic action, ancient and modern. Hardly a mountain range lacks them.

The largest consecutive areas without them are among the plateaux; but in that same province, also, are some of the largest lava-fields.

In Southern Utah there are connected floods of lava, covering an area of 5,000 square miles; and of this area the geologists of the expedition have obtained data for geological maps.

They have also approximately defined the limits of a similar area in Arizona and New Mexico not less than 20,000 square miles in extent, and never before recognized as a connected belt.

Of the conclusions which they draw from their accumulation of volcanic data, one, at least, is of general interest, namely: that eruptions in our western territory will be again resumed, which occurrences may take place at any time. In the past, they have occurred so recently that it is, indeed, surprising that there is no human record of them.

The distribution of the geological formations has been made out with a good degree of accuracy in the portions of the plateau country and Rocky Mountains that have been examined; but in the region of the Cordilleras less has been accomplished, for the reason that all relations there are more complicated and no strata can be traced continuously for great distances. Among the contributions to stratigraphical knowledge are the determination of the Tertiary age of the Sam Pitch coals of

Utah, of the Cretaceous age of the coals of Castle Valley and Southern Utah, and of the Cretaceous age of the disputed coal-series of Colorado. Tertiary, Cretaceous, Jurassic, Carboniferous, and Silurian rocks have been identified by fossils in Utah, and all of these but the Jurassic in New Mexico; in Colorado and Arizona, Cretaceous, Carboniferous, and Silurian; in Nevada, Jurassic, Carboniferous, and Silurian; and in Southern California, Carboniferous and Silurian.

The age (heretofore in doubt) of the shale and sandstone at the base of the series of strata exposed in the Grand Cañon of the Colorado has been ascertained to be primordial.

Of special subjects of study, one of the most interesting has been that of the glacial epoch. The southern limit of the ancient system of glaciers has been ascertained through the entire extent in longitude of the survey, and an attentive examination has been made of the record of an expansion of Great Salt Lake, which occupied the valleys of Utah, while its highest mountain-gorges were choked with ice.

The elaboration of these results into reports for publication has occupied the geologists during the winter-months.

The report of Mr. Marvine is in manuscript, ready for the press, and the same may be said of the report of Mr. Gilbert for the field-work of the seasons of 1871 and 1872, and of that of Mr. Howell. A portion, however, of the notes of the latter gentleman have been put into the hands of Mr. Gilbert to combine with some closely-related examinations of his own, and embody in the report, upon which he is now engaged, of his examinations in 1873.

Professor Stevenson has completed and submitted his report, with the exception of a single chapter. The whole will fill, when printed, about 350 quarto pages.

In the preparation of these reports, the itinerary form, so easy to write, but so inconvenient for use, either by the general reader or by the future student in the same field, has been avoided, and all the material presented has been thoroughly classified. Facts of common character have been brought together, and where their importance warranted, have been briefly discussed in their relations to each other and to cognate facts in other fields; and it is believed that the arrangement is such that the various data will be *readily* accessible to those who shall have occasion to use it.

An atlas of geological maps is in preparation, to accompany the reports.

The general facts of rock-distribution are to be indicated by colors laid upon the topographical-atlas sheets, and special maps will be constructed to illustrate some other features, such as the distribution of glacial phenomena and of thermal springs.

The illustrations with the text will consist of fourteen plates, derived chiefly from photographs of peculiar geological features, and of a large number of wood-cuts, the major part of which are now drawn.

The wood-cuts are chiefly diagrams and sections representing rock-structure, and are strictly explanatory of the text.

The geological collections (without including the fossils and ores) number 2,700 specimens. One of their chief uses has been already subserved in enabling the geologists to study, during the preparation of their reports, peculiarities of texture and composition that could not receive full attention in the field; but a larger portion of them have a permanent value also as material for special lithological study.

It is hoped that at some future day the volcanic rocks, which outnumber all others in the collection, can be placed in the hands of a competent specialist for study.

PALEONTOLOGY.

The fossils number 4,500 specimens, and come from all portions of the area examined. They have had their first (geological) use in identifying the several formations in a great number of localities, and promise to reward richly their paleontological study. A preliminary examination has been made of the invertebrates by Mr. F. B. Meek, the paleontologist, and upon his judgment an estimate has been made of 150 quarto pages of text and 30 plates for the description of the new forms.

The vertebrate remains, including bones of mastodon, horse, camel, rhinoceros, &c., have been submitted to Prof. O. C. Marsh, who will report upon them.

The collections were made by the geologists and mineralogists of the expedition, and by Assistant George M. Keasby, who accompanied one of the parties in New Mexico in the last season with the special errand of gathering vertebrate remains.

MINERALOGY.

During the field-season of 1871, Acting Assistant Surgeon W. J. Hoffman accompanied the expedition as naturalist and mineralogist, and in 1873 Dr. O. Loew joined the survey as mineralogist and chemist.

Besides the collections of these gentlemen, a great many specimens of minerals and especially of ores have been gathered by the officers in charge of parties and by the geologists.

The entire accumulation numbers 1,600 specimens. Dr. Loew has prepared a report to be included in the geological volume, comprising, with a *résumé* of the results of previous years, a full account of his chemical and other investigations. It is now ready for the press, will fill 45 pages, and includes—

1. A report on the agricultural capacities and lands of portions of New Mexico and Arizona, with notes on the geographical distribution of plants, and on several cosmical phenomena.

2. The analyses of all mineral springs encountered, of saline efflorescences and incrustations; also analyses of soils and plants, of coal-specimens, ores, kaolins, and of a fossil resin hitherto unknown.

3. A description of the volcanic rocks of New Mexico and Arizona, with numerous analyses. In some of these rocks, cobalt and nickel were found, an occurrence heretofore not observed.

4. Tables comprising the minerals collected, their occurrence in Nevada, Utah, Arizona, New Mexico, and Colorado. These comprise the collections of the last four years, and are arranged after the chemical system of Professor Dana.

Numerous mining-districts in Colorado and New Mexico were visited, the ores and their geological occurrence described, and specimens collected.

In Colorado, especial attention was paid to the mines of Gold Hill, Central, and Georgetown.

The predominating ores of Gold Hill are the tellurides of gold, silver, and lead; those of Central, auriferous pyrites; those of Georgetown, argentiferous galena.

The principal gold-mines of New Mexico are situated in the Placer Mountains, 30 miles south of Santa Fé, where the precious metal is found free in placers as well as in iron-pyrites.

The chief silver-mines noted in this Territory are those at Silver City and Fort Bayard, where chloride of silver occurs in gypsum and slate,

associated frequently with cerassite, galena, and malachite. These ores are chiefly deposits, no true fissure-veins having as yet been developed. Similar ores occur on the Sierra Madalena, (Socorro mines,) together with frequent deposits of argentiferous cerassite.

True fissure-veins of argentiferous galena occur at La Joya on the Rio Grande Extension, and valuable copper-mines are worked in the Burro Mountains, at Santa Rita, and on the Rio San Francisco in Arizona.

Silicate, carbonate, red oxide, and sulphide of copper are the principal forms in which the copper is encountered. Colorado and New Mexico abound in mineral springs. These springs may be classified, as to their thermal conditions, into hot and cold, or, according to their prominent compounds, into soda, iron, salt, sulphur, lime, and siliceous springs.

Hot salt-springs occur on the Rio San Francisco in Arizona; hot lime and soda springs at Ojos Calientes on the Jemez Creek, New Mexico; cold soda springs at Cañon City, Col.; iron springs on the Arkansas River (Carlisle), and in the Greenhorn Mountain Range a sulphur-spring.

Spectroscopic investigations have always been combined with the analysis, and thus the presence of lithia was detected in most of the classes of springs above mentioned.

NATURAL-HISTORY BRANCH.

The force at disposal has been directed with a view to the accomplishment of the largest possible results, which have proven entirely satisfactory.

Considering the character and extent of the area entered, the attendant expense has been comparatively small.

The subjoined report from Acting Assistant Surgeon H. C. Yarrow, U. S. Army, sets forth the objects, operations, and results more fully.

REPORT OF ACTING ASSISTANT SURGEON H. C. YARROW, U. S. ARMY.

UNITED STATES ENGINEER OFFICE,
GEOGRAPHICAL EXPLORATIONS AND SURVEYS
WEST OF THE 100TH MERIDIAN,
Washington, D. C., June 30, 1874.

SIR: I have the honor to submit the following brief *résumé* of the results of operations in the branch of natural history of the survey under your charge, during the past year, introducing incidentally facts bearing upon the results of the two previous years.

Such a sketch would appear particularly desirable at this time, since as yet, excepting in two instances, the natural-history branch has been unable to publish either notes or descriptions of the specimens collected and studied during the period in question, notwithstanding many hundred pages of manuscript have long been prepared.

The general plan for studying the natural history of the Western Territories has been to collect everything calculated to throw any light on the subject and add to our somewhat limited knowledge of the geographical distribution of animals and plants, and afterward to submit such collections to specialists for study, and a report of the results of their investigations; the specimens finally being presented to the National Museum at the Smithsonian Institution, by which establishment they are distributed to different institutions of a similar character throughout the world.

For the last-mentioned reason, therefore, especial attention has been directed to procure duplicates, in order that, instead of our industry appearing selfish, numbers of learned institutions might partake of the knowledge thus acquired.

Some years since it was held that the possession of scientific acquirements should be only for a favored few; but at the present day more thorough systems for the dissemination of scientific knowledge have been inaugurated.

To the corps under whose auspices this expedition was projected, and is still carried on, is due, to a great degree, the popularization of the study of natural history in this country.

The operations of the natural-history branch of this survey may be briefly stated as follows:

In 1871, the services of Dr. W. J. Hoffman, U.S. Army, and Mr. Ferdinand Bischoff were secured, the former as surgeon and naturalist, the latter as collector, by whose joint efforts many hundreds of specimens were secured in zoology and botany, among which were quite a number hitherto unknown to science. Of this collection, the botanical portion was placed in the hands of Prof. Sereno Watson, of Cambridge, who kindly named the new species, and submitted a report upon the collection, which has been received, and will prove a valuable contribution to our knowledge of the flora of the interesting section of country visited.

The mammals collected have been reported upon by Dr. Hoffman; the birds, by Mr. Ridgway of the 'Smithsonian,' Mr. Henshaw, and myself; the reptiles and fish, by Prof. E. D. Cope and myself; and the insects, of which many thousands were secured, by Mr. Ulke, Professor Thomas, Professor Uhler, and others. In addition to those received at this office, many other specimens were collected, which, however, unfortunately, were either lost in transit from the West or destroyed in the great Chicago fire.

The collection of 1871, while not as large as either that of 1872 or 1873, is extremely interesting, from the fact that many of the rarer forms of zoological life were met with as well as important data obtained relative to their general distribution and occurrence. This entire collection has been deposited in the National Museum.

In 1872, recognizing the great value of the collections already made by the Engineer Corps of the Army, and being assured that to the scientific world researches in natural history, especially on our western frontier, would add greatly to our knowledge of the zoology of that region, you permitted unusual facilities for the prosecution of such labor, the results proving the wisdom and foresight of such a course, since a collection was made seldom rivaled by that of any similar expedition having but two collectors.

It is but proper, however, to add that several of the members of the survey contributed largely to the general stock of specimens.

In this collection there were about eight hundred bird-skins, most of them rare and valuable; a large number of mammals; several hundred fish, of which no fewer than sixteen species were new to science; and many reptiles, insects, shells, plants, &c., embracing in all probably 5,000 specimens. Not the least important specimens in the collection were a number of Indian crania, obtained at considerable risk from the Ute burial-places and ancient mounds in the valley of the Great Salt Lake, as well as numerous implements, both ancient and modern, used by the aborigines.

This entire collection has been apportioned among eminent special-

ists for determination, most of whom have already reported, their manuscripts awaiting publication.

The mammals have been identified and reported upon by myself; the birds, by Mr. Henshaw and myself, with the assistance of Mr. Ridgway, of the Smithsonian Institution; the reptiles and fishes, by Prof. E. D. Cope and myself; the insects, by Mr. Ulke, Professor Uhler, Professor Cresson, Dr. Hagen, Baron Osten-Sacken, Professor Thomas, and Mr. Edwards; and the shells by Mr. G. W. Tryon, jr., of the Philadelphia Academy of Natural Sciences.

The botanical collection has been worked up by Prof. Sereno Watson, of Cambridge, who had charge of, and reported upon, the collection of 1871.

The Indian crania have been forwarded to the Army Medical Museum, and we are assured by the officer in charge that the donation is a valuable one.

In 1873, the natural-history party was enabled to take the field early, and, through the indefatigable exertions of the collectors, results were secured even exceeding those of the previous year; the official record showing the following number of specimens:

"Seven Indian crania.
"One hundred and sixty mammals.
"One thousand and two hundred bird-skins.
"Five hundred birds eggs.
"Twenty-five birds nests.
"Fifty birds crania, skeletons, and sterna.
"One hundred and forty-five reptiles.
"Five hundred and five fish.
"Five hundred beetles, (*Coleoptera.*)
"One hundred and fifty butterflies, (*Lepidoptera.*)
"Five hundred grasshoppers, (*Orthoptera.*)
"Thirteen lots of flies, (*Diptera.*)
"Thirteen lots of bugs, (*Hemiptera.*)
"Twelve lots of worms, leeches, larvae, &c.
"Seven lots of ants, (*Formica.*)
"Fifty-five lots of shells, land and fresh-water.
"Twenty-four lots of dragon-flies, (*Neuroptera.*)
"Twenty-eight lots of bees and wasps, (*Hymenoptera.*)
"Twenty-six lots of spiders, scorpions, &c., (*Arachnida.*)
"Fifteen thousand plants, embracing at least one thousand and five hundred species."

This collection contains many new as well as many rare species, seldom to be found in public museums. As in former years, the plan has been continued of distributing the specimens to eminent scientists, and from the majority of these gentlemen reports have already been received and are now ready for printing.

Thanks are due to the following gentlemen, who have so kindly aided in many ways, in every case giving their valuable services gratuitously to the elucidation of scientific material connected with the expedition, viz: Prof. Joseph Henry, Prof. S. F. Baird, Prof. E. D. Cope, Prof. S. A. Allen, Prof. A. E. Verrill, Prof. O. C. Marsh, Dr. H. Allen, Dr. H. Wood, jr., Dr. George A. Otis, U. S. A., Dr. J. J. Woodward, U. S. A., Prof. A. Agassiz, Dr. H. A. Hagen, Mr. W. H. Edwards, Mr. Theodore L. Mead, Dr. P. H. Uhler, Mr. H. Ulke, Prof. Cyrus Thomas, Prof. Townend Glover, Mr. Robert Ridgway, Mr. G. Browne Goode, Prof. E. T. Cresson, Mr. W. G. Binney, Mr. G. W. Tryon, jr., Prof. Sereno Watson, Mr. George Thurber, Prof. Thomas. P. James, Dr. George Vasey,

Baron Osten-Sacken, Mr. G. N. Lawrence, Mr. Thomas Bland, Prof. S. Olney, Mr. R. H. Stretch, Mr. Aug. R. Grote, Dr. William Holden, Mr. Edward Norton, Dr. Elliott Coues, U. S. A., Prof. Asa Gray, Mr. J. H. Milner, Dr. A. S. Packard, jr., Mr. S. C. Scudder, and others.

In conclusion, I beg leave to express thanks for the great interest manifested in this branch of the work committed to your charge as well as for the facilities you have always afforded for making collections.

With the hope that, as in the past, the future may find you alive to the importance of the natural-history wants of the period, I have the honor to be, very respectfully, your obedient servant,

H. C. YARROW,
Surgeon and Naturalist to Expedition.

Lieut. G. M. WHEELER,
Corps of Engineers, U. S. Army.

PHOTOGRAPHS.

As heretofore, a photographer has accompanied the expedition, following a route from Santa Fé westward, via Fort Wingate; thence to Camp Apache, and the vicinity of the Sierra Blanca range, Arizona; thence northward, *via* old Fort Defiance, Moquis Pueblos, and the Cañons of the Colorado.

A great variety of negatives, of which a few prints have been taken, were secured, illustrative of natural scenery, the habits and customs of the Indian tribes, ancient ruins, &c.

During the season, the executive officers of parties have gained valuable experience in the subjects of observation intrusted to their charge.

The property, purchasing and disbursing branches have been faithfully and efficiently filled by Assistants Francis Klett and George M. Lockwood.

OFFICE.

While the expedition of 1873 was in the field, three draughtsmen and one computer were employed in the office, and completing results to the close of the season of 1872, both topographical and meteorological, and those of 1873 are well advanced.

The great mass of geographical information obtained annually obliges this method, which proves to be most economic.

CONCLUSION.

The progress and improvement of the survey have passed through successive stages since its commencement in 1869. It is believed that in its present efficient state it answers a want of the War Department and the country, and has at its foundation a judicious economy.

The results are available to other executive departments of the Government than the War Department, and incidentally to the industries of the region surveyed. While suggesting the propriety of the continuance of the survey, a few of the many classes of information are here noted, the results from which are believed to be of constant necessity and usefulness in the War Department:

1st. The published maps, profiles, and compiled distances over present and future routes of communication and supply that look to a saving in cost of transportation of all materials and munitions of war and other supplies forwarded through the Quartermaster's Department of the

Army. As a correct understanding of the topographical features of a country is necessary to all military operations, either in times of war or peace, the necessity for the acquisition of this information in a systematic form at the War Department, and its dissemination through the different branches of the military service, becomes apparent.

2d. The establishment of routes of communication necessary for the supply of interior posts. For an understanding of the above, the interlying country requires thorough examination.

3d. Critical routes to be followed in the interchange of troops between distant stations when demanded.

4th. New and shorter routes for forwarding recruits to their companies and stations.

5th. Routes for scouts pursuing hostile or unfriendly Indians.

6th. The selections of sites for new military posts established in advance of, or as safeguards to, civilization.

7th. Routes for troops when called out for the protection of miners or settlers.

8th. A knowledge of the resources of the country surrounding the military establishments, and its capacity for furnishing supplies.

9th. Routes of transit when troops are ordered to remote points in aid of the civil law.

10th. A knowledge of the character and habits of the several Indian tribes, and their disposition toward each other and toward settlers.

The above are a few of the classes of examinations necessary and valuable to the several Bureaus of the War Department and to the commanders of troops in their pioneering into the unoccupied and comparatively inaccessible portions of the western interior.

To obtain such information that should be at all times immediately available for the uses of the War Department, such observations as are necessary for an *accurate delineation and description of the surface and resources of the area surveyed* must be made. This calls for geographical surveys in their highest and broadest sense.

The position of the cognate branches of science in carrying on so important a work must naturally be subservient to the exact science necessary to the delineation of the surface with accuracy. Meanwhile, the co operation of specialists in the branches above referred to will, without largely increasing the cost, enhance that portion of the results relating to the resources of the region surveyed, and to them the best facilities for the prosecution of their inquiries are afforded, as also most excellent opportunities for the proper application of their results.

In order that the survey may be continued at the standard proposed in the Progress Report for 1872, the estimate below submitted will be required to be appropriated, so that one of the units of force may take the field, and within the year, or shortly thereafter, publish its entire and complete results.

The survey is capable of expansion to meet the wants of the Government, but its operations cannot be made satisfactory except at least one of the units of force is appropriated for.

The law for the present year admits of the prosecution of the survey with the force at its disposal in any portion of the area west of the one hundredth meridian.

The special area for the season of 1874 has been authorized by the War Department.

Of mountainous areas very little known, whose present and prospective mining developments indicate that this industry will soon enter them, are portions of New Mexico, represented by that part of atlas-rectangles 77, 84, 78, and 85, west of the Rio Pecos and east of the Rio

Grande; also, in rectangles 47, 48, and 57, and portions of 65, along the east base of the Sierra Nevada range.

It is not deemed essential or advisable to have limited long in advance special areas to be occupied in any one year, although, so far as practicable, the areas of several years should be made to conjoin, yet the survey should be held as an intact organization, prepared to carry on its work in any portion of the interior west of the one hundredth meridian into which it shall be ordered by the War Department.

As the surveys of the General Land-Office are being extended into the mountainous mining-districts, and as there are boundary-lines between political divisions yet to be marked, I would suggest the propriety of an interchange of results between the General Land-Office and this survey.

The use of details of the former prevents the necessity of duplication of work in certain valley-areas, while points could be furnished checking standard meridians and bases, prominent points on boundary-lines, initial points for the surveys of mining claims and areas, &c.

The amount required for the prosecution of the field and office work of the survey for the fiscal year ending June 30, 1876, by the unit of force proposed, is $95,000. No less sum than this can be used with the same resulting degree of economy.

The probable distribution of expenditures under this appropriation would be as follows:

Expense of nine parties in field and office	$58,000
Transportation, including purchase of animals	8,500
Purchase of materials, outfits, &c	6,500
Subsistence of parties in the field	6,400
Forage, including winter-herding	7,500
Repairs of instruments	1,500
Office-rent, fuel, storage, &c	3,100
Contingencies, including erection of monuments and observatories at astronomical stations	3,500
Total	95,000

Amount appropriated to continue explorations and surveys west of the one hundredth meridian for the fiscal year ending June 30, 1875	$30,000 00
Amount allotted from balances existing June 30, 1873, and made available by act approved June 23, 1874	60,000 00
Amount remaining on hand at close of fiscal year ending June 30, 1874	25,889 45
Amount required for field and office for fiscal year ending June 30, 1876	95,000 00

All of which is respectfully submitted.

GEO. M. WHEELER,
First Lieutenant Corps of Engineers, in charge.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. Army.

F F 2.

PLAN FOR PUBLICATION OF REPORTS AND MAPS, WITH ESTIMATES.—SUMMARY OF PUBLICATIONS TO PRESENT TIME.

UNITED STATES ENGINEER OFFICE,
GEOGRAPHICAL EXPLORATIONS AND SURVEYS
WEST OF THE 100TH MERIDIAN,
Washington, D. C., June 30, 1874.

GENERAL: The estimate of $95,000, submitted as the amount necessary to continue the work under my charge for the fiscal year ending

June 30, 1876, covers the expense only of the field and office work of the survey, but not the publication of maps or illustrations for the survey-reports.

In the act approved June 23, 1874, the amount of $25,000 was appropriated for the fiscal year ending June 30, 1875, for illustrations for the volumes to be published.

The greater number of the manuscripts for the six volumes proposed (see Annual Report of the Chief of Engineers for 1873, p. 1717) are ready for the press, and only await the preparation of the illustrations for the same, which will be begun early in the coming fall.

The necessary changes, in the manner proposed in the last annual report, for the form and scope of the volumes are as follows: Volume 1 is to include the general report of 1873, and condensed reports upon all the mining-districts visited since the year 1871. It should be complete soon after the return of the expedition of 1874. Volume 2 is to include reports upon the astronomical stations of 1873. The manuscript will be ready for the press as soon as the observations necessary for the connection of the astronomical observatory at Ogden, Utah, with the U. S. Naval Observatory at Washington, D. C., are computed. Volume 3 is to embrace the subjects proposed in the annual report of this year. It is somewhat doubtful whether it can be published during the present fiscal year. Volume 4, as indicated in the main body of the report, approaches completion, and ought to be ready for the press by October 10. The examination of fossils and the preparation of reports upon paleontology are going on while the parties are in the field, and ought to be well advanced by the 1st of October. This volume will also contain a report upon the vertebrate fossils collected in 1873. Manuscript reports for volume 6 are nearly ready, and can go forward to the printer during October.

It has been found impossible to include in the present annual report total results up to date in the astronomical, meteorological, and topographical branches, as stated in my last annual report. They are all brought closely to completion, however; and the reports relating to the cognate branches of the survey, as therein indicated, will be hereafter brought out in special form.

The present field-season must necessarily be a short one, and during the coming year it is deemed possible to establish a complete harmony between field and office work and results so that, as nearly as possible, within the fiscal year, the final results shall be placed in publication-form.

PUBLICATIONS.

Since the inception of the work under my charge, the following separate publications other than maps relating thereto have appeared: Preliminary Report, 1869, (octavo;) Preliminary Report, 1871, (quarto;) Table of Camps, Distances, &c., 1871 and 1872, (quarto;) List of Mining-Questions; List of Mining-Districts Visited, 1871, 1872, and 1873; Landscape and Stereoscopic Views taken in the years 1871, 1872, and 1873; Preliminary Report upon the Fishes, 1871 and 1872, by Prof. E. D. Cope, (pamphlet;) Annotated List of the Birds of Utah, collected in 1872, (pamphlet.)

The following reports have been submitted to the Engineer Department, with a request for their publication, and it is believed have gone forward to press: Progress Report, 1872; Report upon the Botanical Collections of 1871, 1872, and 1873; Report upon the Ornithological Collections of 1871 and 1872.

A Report upon the Determination of the Astronomical Co-ordinates of the Stations at Cheyenne, Wyoming, and Colorado Springs, Colorado, quarto, was issued in January, 1874.

MAP-PUBLICATIONS.

Topographical atlas. — An advanced-sheet issue of this atlas has been photolithographed during the year. It contains (1) title-sheet, (2) legend-page, (3) basin-chart, (4) progress-map, and sheets Nos. 50, 58, 59, and 66. A 2,000-copy edition has been published, and 486 sets distributed; 500 copies of sheets Nos. 50, 58, 59, and 66 have been printed on thin paper for preliminary distribution.

Proofs have been presented of sheets Nos. 50, 59, and 66, executed by the crayon-process. No. 59 is within a few days of completion. In addition, there are in the hands of the lithographer, of which proofs are to be furnished soon, (1) index-map, (2) general topographical map of the area west of the Mississippi River, and (3) an explanation-sheet. Sheets 49 and 67 are in an advanced state of preparation, and go forward soon to the lithographer. Sheets 57, 65, 75, 76, 83, and portions of 77 and 84, are in process of construction on a scale of one inch to eight miles. The southeastern, northeastern, and southwestern parts of sheet 61, and the southeastern quarter of sheet 52, are being constructed on a scale of one inch to four miles.

All of the sheets above mentioned will doubtless be completed and published during the coming year. The several photographic copies of the preliminary maps for office-use are printed by the photographer of the expedition. There have been made, during the year, issues of the preliminary maps of 1869 and 1871 and of the office-map of 1872.

There is a large and increasing call for maps of the comparatively unknown regions west of the one hundredth meridian, and the edition already authorized will be insufficient to meet the wants of the present fiscal year. The atlas of geological maps is referred to in the main body of the report. From material gathered, fourteen sheets are proposed for publication.

The following estimate for the publication of maps and illustrations for the reports is submitted for the fiscal year ending June 30, 1876. The amount is the same as that appropriated for the present fiscal year.

For preparation, photolithographing, engraving, and printing atlas and other topographical maps, including the field-work of 1874	$15,000
For preparation, photolithographing, engraving, and printing geological maps, to include the work of the field-season of 1873	2,500
For engraving and printing plate and other illustrations for reports	7,500
Total	25,000

The amount appropriated for engraving and printing illustrations for the reports of explorations and surveys west of the one hundredth meridian, for the fiscal year ending June 30, 1875, is $25,000.

Amount required for the preparation, engraving, and printing of topographical and geological atlas, maps, and illustrations for reports for the year ending June 30, 1876, $25,000.

A copy of the progress-map is herewith, showing approximately the areas surveyed up to the close of the field-season of 1873.

Very respectfully, your obedient servant,

GEORGE M. WHEELER,
First Lieut. of Engineers, in charge.

Brig. GEN. A. A. HUMPHREYS,
Chief of Engineers, U. S. Army.

APPENDIX FF 3.

REPORT ON PALEONTOLOGY.

UNITED STATES ENGINEER OFFICE,
EXPLORATIONS AND SURVEYS WEST OF THE 100TH MERIDIAN,
Washington, D. C., October 15, 1874.

GENERAL: I have the honer to forward herewith a special report received from Prof. E. D. Cope, paleontologist to the expedition of this season, embodying some of the results of his labors in portions of New Mexico, up to the 27th of September. This report contains new and valuable information relative to vertebrate fossil remains.

Very respectfully, your obedient servant,

GEO. M. WHEELER,
Lieutenant of Engineers, in charge.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. Army.

REPORT OF PROF. E. D. COPE, PALEONTOLOGIST.

CAMP ON GALLINAS CREEK, *September* 27, 1874.

SIR: In accordance with your instructions to forward a report of proceedings, I beg leave to state that I returned to this camp from Tierra Amarilla on the 15th of the month, and have remained here ever since. We have been mostly employed in examining the bad lands of the Eocene of the divide between the Chama and San Juan Rivers, and in collecting the vertebrate fossils which their beds contain. A little time has been devoted to the Cretaceous beds forming the rim of the Basin. From the Eocene beds, more than seventy-five species of vertebrates have been obtained, many of which are new to science, and others are largely illustrated by additional remains. Four species of a new order, the *Toxodontia*, have been discovered, and our knowledge of the structure of other peculiar forms enlarged. Interesting relations between the Cretaceous and Tertiary beds have been observed.

Mr. Shedd has been assisting in making collections and taking his meteorological observations at the stated times.

The health of the party continues good, and we hope to move camp to another point ere long.

Very respectfully, your obedient servant,

EDW. D. COPE,
Paleontologist.

Lieut. GEO. M. WHEELER,
Corps of Engineers, U. S. A.

NOTES ON THE EOCENE AND PLIOCENE LACUSTRINE FORMATIONS OF NEW MEXICO, INCLUDING DESCRIPTIONS OF CERTAIN NEW SPECIES OF VERTEBRATES, BY PROF. E. D. COPE, PALEONTOLOGIST TO THE EXPEDITION.

PART I.

One of the results of the examinations made during the field-season of 1874 is the discovery of an extensive series of deposits of Eocene age. These indicate the existence, during early Tertiary time, of an extensive lake of fresh water in that part of New Mexico now drained by the tributaries of the Chama River on the east and the San Juan River on the west. This lake received the remains of the fauna of its shores and other regions adjacent, which have been preserved and obtained by the members of the expedition detailed by Lieutenant Wheeler for its investigation, in considerable numbers.

The shore of this lake was formed by rocks of the Cretaceous formation of an age near the No. 3 of Meek and Hayden. In approaching it from the east, we traverse the sandstones of Cretaceous No. 1, both horizontal, and tilted at various angles, and find No. 2 resting upon it frequently unconformably, and tilted at higher angles, fre-

quently 45°, sometimes 50°, to the west and southwest, and containing numerous fossils, as *Inoceramus*, etc. The upper sandstones of this formation pass into a brackish or fresh-water formation, which includes a bed of lignite, of sometimes 50 feet in thickness. Above this rests, conformably where seen, a moderate thickness of rather soft marine rocks, containing numerous shells, *Acephala*, *Gastropoda*, and *Cephalopoda*, including *Oysters*, *Baculites*, and *Ammonites* resembling *A. placenta* most, with sharks' teeth. Resting unconformably on these, with a much reduced dip, is a mass of brown and reddish sandstones, some 1,500 feet in thickness, inclining perhaps 10° south and southeast. These pass continuously into the superincumbent red and gray marls, alternating with brown and white sandstone of the fossiliferous beds of the Eocene. The observed part of these beds is about 1,500 feet in depth.

A considerable number of species of *Vertebrata* have been obtained, a large majority of which are *Mammalia*. While it is premature to attempt to determine fully the character of the fauna, enough has been ascertained to indicate marked differences from that of the Bridger group of Wyoming. It is peculiar in the entire absence of the genus *Palæosyopsos*, so characteristic of the former, and its replacement by *Bathmodon*, which has never been recorded from the Bridger formation. The abundant species of *Hyrachyus* of the Bridger are here represented by a single one of small size, which occurs but rarely, while its companion, *Hyopsodus*, is very rare or wanting. While gar-remains are abundant in both, the *Amiidæ* and *Siluridæ* have not yet rewarded our examinations. The characteristic genera of the New Mexican fauna are *Bathmodon*, Cope; *Hipposyus*, Leidy; and *Phenacodus*, Cope, genera which it shares with the *Bathmodon* bed of the Green River formation of the Bear River Wyoming. There is in all respects so close a resemblance between these deposits as to lead to the belief in their horizontal identity, and with other reasons, to give to the southern basin a higher antiquity than belongs to the celebrated Bridger series. The interesting fact that the teeth of six or seven species of sharks and one *Ostrea* have been deposited with the mammalian remains indicates that the marine Cretaceous rocks formed the coast-material of this lake, and the earlier period of its deposit is probable on various grounds, to be considered at a future time. The facts are all confirmatory of the view already expressed by the writer that the population of the Bridger epoch was derived by migration from a southern region.

Perhaps the most important addition to paleontological science obtained during the course of the investigation is the discovery of four species of two new genera, *Calamodon* and *Ectoganus* of *Toxodontia*, an order which has not been heretofore identified as having existed on the North American continent.

DESCRIPTION OF SPECIES.

ECTOGANUS GLIRIFORMIS, *gen. et sp. nov.*

Char. gen.—This genus rests on a number of remains of the crania of three species, including principally teeth, in a good state of preservation, all found in appropriate relations by the writer. The teeth include incisors, molars, and premolars, it is believed, of both superior and inferior series.

There are two types of gliriform incisor-teeth, and of one of these in the largest species three sizes. In the one, the teeth are elongate, compressed, convex in both directions on the anterior; are convex or angulate in section at the posterior face. In all, the enamel is confined to a band on the anterior face, extending more or less on one side or the other, the naked dentine extending prominently backward at the middle and basal portion of the shaft.

In the larger size, this portion is subacute behind; in the smaller, obtuse. Teeth of this type are of three sizes, the smaller two the most compressed and with narrowest enamel. Those of the second type are of one, an intermediate size, and are shorter than those of the others and less compressed. One of their faces is concave in both directions, and is covered with enamel from the apex of the tooth for some distance posteriorly. From its terminus on the concave side, the enamel borders retire to the sides of the convex front.

There are three molars of the superior and many of the inferior series available for present determination. The superior are all remarkable for the great exposure of their external faces as compared with their internal, and the extension of the enamel on the outer face of the very thick external root, which is not distinguished from the crown. The true molar has three roots, and the crown is longer antero-posteriorly than transversely. It consists of two transverse tubercular ridges, connected by a medium oblique longitudinal ridge. The premolars have two of the roots connate, forming a support to the greater part of the crown. The worn surface is in form something like the Greek ω, the deep emargination being internal. The inferior molars have greater antero-posterior than transverse diameters. The enamel is more extended on one side than the other, covering the exposed portions of the roots. The grinding surface is plane, and has the form of a horizontal ϖ: the limbs being angulate, as in the Greek Σ.

It is impossible to determine the affinities of this curious genus with the material

at present in my hands, but it is evidently nearer to the South American *Toxodon*, Owen, and *Typotherium*, Gervais, than anything yet discovered in the North American Tertiaries. It is no doubt related to the *Anchippodus*, Leidy, and *Tillotherium* Marsh, (which Marsh observes may be identical,) but differs from both in many points of the dentition.

Char. specif.—All the incisors are regularly convex in front. The surface of attrition of the large ones truncate, of the small ones obliqne. The section of the large ones near the base is diamond-shaped, with one acute angle truncate and the other rounded. There are some shallow grooves on the sides, and on one side a more pronounced longitudinal shallow angulation. The enamel of these and of all the molars is smooth, and there are no cingula on the latter. The transverse crests of the unworn true molars support two tubercles, and the inner extremities of the crests of the premolars are produced in accordance with the obliqne wearing of the incurved crown in mastication.

Measurements.

	M.
Length of incisor, largest, type 1	.043
Width of incisor, largest, type 1	.013
Depth of incisor, largest, type 1	.018
Length of incisor, medium, type 1	.034
Width of incisor, medium, type 1	.006
Depth of incisor, medium, type 1	.014
Depth (?) of incisior, last, type 1	.009
Width of incisor, last, type 1	.004
Length of incisor, type 2	.031
Width of incisor, type 2	.006
Diameter of crown of premolar { longitudinal	.010
Diameter of crown of premolar { transverse	.010
Length of enamel of face externally	.013
Length of enamel of face posteriorly	.005
Length of crown of posterior upper molar	.016
Width of crown of posterior upper molar	.012
Length of crown of posterior lower molar	.012
Width of crown of posterior lower molar	.009

Size about that of a fully-grown hog, (*Sus scropha.*)
Portions of several individuals have been found.

CALAMODON SIMPLEX, *gen. et sp. nov.*

Char. gen.—Molar teeth subcylindric, prismatic, rootless; the crown only distinguished by its investiture of enamel, which exhibits a weak marginal inflection for a portion of the length. Enamel extending in a band on one or both sides of the tooth to the base. Incisors rodent-like, curved, with a band of enamel on the anterior face, and obliquely-truncate extremity.

A number of specimens, probably representing this genus, have been found, and I select as typical those of an individual in which the molar and incisor teeth occurred together. The form is evidently allied to *Ectoganus*, as the close resemblance of the incisor teeth demonstrates, but the molars are of a much more simple type than anything yet discovered in this group, imitating superficially those of some *Edentata*.

Char. specif.—Molar (? superior) longitudinally bent, the convex (outer) face covered with enamel to the base. Enamel extending a much shorter distance on the inner face, and soon worn through by attrition on one of the other faces. Section of the base of crown a subquadrate oval. A slight inflection of enamel on the inner and a still weaker one on the (?)posterior border of the triturating face. Enamel with slight longitudinal ridges. Incisor much curved, strongly convex in transverse section, the enamel obscurely longitudinally ridged on both sides near the border. Section of one side slightly concave.

These and other specimens indicate an animal at least as large as the American tapir.

Measurements.

	M.
Length of a molar	.042
Diameter of the same	015
Diameter of incisor, transverse	.019

CALAMODON ARCAMŒNUS, *sp. nov.*

This *Troxodont* is represented by a portion of the skeleton of a specimen including several teeth, and most probably by portions of another, which includes a large and perfect inferior incisior-tooth. The former displays the alveoli for molars and incisors,

showing the one-rooted character of those of the lower jaw, and the deep implantation of the incisor below the antepenultimate molar. The number of molars indicated by the ramus is five, the anterior in close contact with the single large incisor. The molars are subquadrate in section, the last a little longer than broad. The only one in which the crown is preserved exhibits a short crown, with its inferior enamel border notched on two, and oblique on two sides, and the external layer of the root swollen above it all round. The summit of the crown is worn, and is divided subequally by a transverse, rather shallow, groove. One division of the crown exhibits two dentinal areas in transverse line, the other three small ones in a curved line. The extremity of the curved incisor is rodent-like, and regularly convex on the anterior face and entirely smooth. The posterior or grinding face is convex in cross-section.

A large lower incisor of another individual is about five inches in length and one and a half in depth, without the increase of elevation of the superior or interior edge, as is seen in *Ectoganus gliriformis*. This edge is obtusely rounded, and instead of being obliquely leveled to meet the masticatory surface of the extremity, is abruptly truncate, the masticating face turning off at one side of the shaft. The enamel is smooth and of equal width and convexity throughout.

Measurements.

	M.
Elevation of crown of molar	.013
Length of crown of molar	.015
Width of crown of molar	.013
Diameter of incisor^{m}. 010 from tip	.013
Length of series of five molars	.090
Depth of jaw at third molar	.055
Thickness of jaw at third molar	.035

CALAMODON NOVOMEHICANUS, *sp. nov.*

Represented by a superior incisor-tooth of a species of smaller size than either of those already described, and differing in various respects from those of the *C. simplex*, of which a fine specimen has been obtained since it was first described. Both anterior and posterior edges are protected by a convex band of enamel; and the triturating surface is tranverse in the direction of the depth, and oblique in that of the width. The shaft increases in depth toward the root and is longitudinally concave on one face and convex on the other. The enamel bands are most extended on the convex face, and unite on that side round the triturating face and present an abrupt emargination on the middle of their convex border. The other, being formed of dentine only, is deeply worn by attrition.

Measurements.

	M.
Length of fragment	.038
Depth at fracture	.018
Depth at grinding face	.011
Width at grinding face	.009

This species differs from the supposed *C. simplex* in this incisor in other respects than in the smaller size. The latter is concave on both sides, and on the lower border; the former convex on one side, and on the lower border.

ESTHONYX BISULCATUS, *gen. et sp. nov.*

Char. gen. (?).—Incisors of two forms; the inferior subgliriform, but not growing from persistent pulps; the enamel covering a long and narrow external vertical face, and terminating above the alveolus, thus distinguishing crown and root. The other form of (?)incisor with the apex encased in enamel, but extending much farther on the outer than the inner side; the crown compressed, not wider than the root. Molars supporting two V's with rounded apices directed outward, the posterior soon wearing into a triangle lower than the anterior. The anterior elevated and transverse only distinguished from a triangle by a notch on the inner side. Last lower molar with this anterior transverse triangle, a diagonal ridge and a heel with raised border.

The type of this genus is *Ectoganus bisulcatus*, Cope, and a second species is *E. burmeisterii*, Cope. It differs from *Ectoganus* as well as from *Anchippodus* in the far less gliriform character of the incisor teeth, which may be compared with the extremities of the slender fingers of some monkeys with narrow nails.

Char. specif.—A species about the size of the *Capybara* is represented by the greater part of the dentition of the lower jaw, which includes representatives of both kinds of incisors already described under the characters of the genus. The rodent-like form is less typical of the genus than in the *E. gliriformis* in being rather shorter and furnished with a less extensive external enamel-plate. The dentinal column projects well internally, giving the tooth a regularly oval section. The incisor of the second form has the in

ternal as well as the external enamel-face, and the former possesses a longitudinal angle bounding its concavity. The grinding-face of the molars and some of the premolars is ϖ-shaped as in the other species, but the anterior limb of the figure is much thickened on the inner face, so as to have a triangular form, the base being inward. This base is notched by a second groove of that side of the tooth, which interruption is obliterated by prolonged attrition. This portion of the crown is elevated above the posterior, in consequence of the more rapid removal of the latter by trituration. The large internal and external grooves continue nearly to the base of the crown, as in the larger species. The last inferior molar is longer than the others, and is three-lobed, forming by its base nearly an isoceles triangle. The heel is formed by the backward production of the posterior convexity of the ϖ, the central line of the figure forming a diagonal ridge across the middle of the tooth.

The mandibular ramus is of a deep compressed form.

Measurements.

	M.
Length of three consecutive molars	.0250
Length of last two molars	.0210
Length of penultimate molar	.0084
Width of penultimate molar	.0062
Length of last molar	.0112
Width of last molar	.0070
Length of incisor, second form	.0250
Diameter of incisor, second form	.0050
Diameter of incisor, first form, transverse	.0030
Diameter of incisor, first form, antero-posterior	.0070

ESTHONYX BURMEISTERII, *sp. nov.*

A species more nearly allied to the *E. bisulcatus* than to the type of the genus is represented by a portion of the right mandibular ramus, with the last molar tooth in perfect preservation. While the jaw is of depth similar to that of the *E. bisulcatus*, it is more slender in its proportions. The molar, also, while of nearly the same length, is relatively narrower, especially in its anterior portion. The crown of this tooth is worn in the specimen, and the anterior portion is elevated above the posterior, and displays a trace of the notch of the inner margin already observed in the species last described. The composition of the tooth is similar in other respects. No cingular; enamel smooth.

Measurements.

	M.
Length of last lower molar	.009
Length of last lower molar from anterior tubercles	.0060
Width { anteriorly	.0050
Width { posteriorly	.0025
Depth of ramus at last molar	.0240

This species is dedicated to Prof. Hermann Burmeister, director of the museum of Buenos Ayres, who has studied the group of *Toxodontidæ*, and given us an excellent account of their osteology.

ESTHONYX ACER, *sp. nov.*

Char. specif.—Established on a portion of the lower jaw, in which the last four premolars remain. They resemble those of the species already named, except in the anterior one of the series. This tooth in *E. acer* assumes the form of a premolar, the posterior V becoming a curved median cutting edge, and the anterior V opening into a crescentoid section; it rises to an acuminate apex, having thus a rather sectorial character. In the last three molars, there is a small tubercle at the inner base of the posterior limb of the anterior V. Posterior V much lower; enamel smooth.

Measurements.

	M.
Length of four last molars	.035
Length of three last molars	.026
Length of penultimate molars	.008
Width of penultimate molars	.005
Length of last molar	.011
Width of last molar	.005
Depth of jaw at last molar	.020

This species differs from the *E. bisulcatus* in the modified form of the last premolar; in the latter, it is relatively larger and more like the true molars. The last molar of *E. acer* is more like that of the *E. burmeisterii*, but the mandibular ramus of that species is relatively much deeper and similar to that of *E. bisulcatus*.

ESTHONYX MITICULUS, *sp. nov.*

Represented by portions of mandibular rami of three or four individuals of much smaller size than any of those referred to the species already described. There are represented two premolars and three molars; other teeth are lost. The molars differ from those of the three species named in lacking the notch or groove on the inner side of the anterior triangle of the crown, which constitutes it a V in those species, giving the worn surface a more simply sigmoid form; the anterior portion is, moreover, not materially more elevated than the posterior. The last molar has a large heel, an inner and two anterior tubercles when little worn. The premolars preserved are each two-rooted, the last is like the corresponding one in *E. acer*, the penultimate without heel or inner tubercles.

Measurements.

	M
Length of three true molars, (No. 1)	.0120
Length of two last premolars, (No. 2)	.0064
Length of first true molar, (No. 1)	.0040
Width of first true molar, (No. 1)	.0030
Depth of ramus at first true molar, (No. 1)	.0080

The worn surfaces of the first and second true molars are much like those of the corresponding teeth of *Menotherium*, Cope. That genus differs in the reduced form of the last inferior molar and in the premolars.

MENISCOTHERIUM CHAMENSE, *gen. et sp. nov.*

Char. gen.—Molars three, with two continuous external crescents and two internal tubercles, except on the posterior, where there is but one, the anterior conic tubercle. The posterior tubercles on the other molars crescentoid in section. A well-developed crescent between the anterior tubercle and anterior crescent, and an oblique crest extending from the latter to the adjacent horn of the posterior inner tubercle. Two external crescents on the last premolar.

This genus presents a curious combination in the structure of its molars of the character of *Palæosyops*, *Hyopotamus*, and *Hipposyus*. It is exceptional among the ungulates of the same fauna in the number of crescents of the molars.

Char. specif.—Last molar with the oblique inner posterior crest terminating at the posterior margin of the crown. Prominent external ribs at the point of connection of the external crescents of the crown. No cingula; enamel entirely smooth.

Measurements.

	M.
Length (externally) of last four molars	.029
Length of true molars	.022
Length of penultimate	.009
Width of penultimate	.010

This animal was about the size of the raccoon, and probably had the habits of the tapirs.

BATHMODON SIMUS, *sp. nov.*

Represented by the remains of a great number of individuals, including all parts of the skeleton, dentition, &c., but especially by one of the most complete of these, which possesses, among other portions, the premaxillary bones. These indicate a species very distinct from the *B. radians*, Cope, and one approaching the *Metalophodon armatus* in the structure of the molar teeth.

The canine teeth have cylindric roots and trihedral crowns, the section of the latter forming a nearly equilateral spherical triangle. The crown of the inferior canines are shorter, and have one concave side. The superior molars support two crests, which are nearly parallel on the single and last tooth of this type. The posterior crest is composed of two portions, the posterior conic and the anterior flatter, and which becomes the external posterior crescent on the penultimate molar. The anterior cingular crest is very well developed on the last lower molar.

The premaxillary bone is short and stout, and descends steeply from an elevated front, presenting its three teeth downward. The canine follows closely from an elevated rib on the side of the face. Behind it is a considerable diastema. The humerus is a very stout bone, and the femur is rather slight in comparison with it.

Measurements.

	M.
Length of bases of last three molars	.083
Length of basis of last molar	.026
Width of basis of last molar	.035

	M.
Diameter of canine at base	.025
Length of penultimate inferior molar	.030
Width of penultimate inferior molar	.021

Individuals of larger size than the above are more common. Measurements of one of these are:

	M.
Length of last superior molar	.032
Width of last superior molar	.043
Diameter of crown of canine, (another species)	.030

This is the especially characteristic large mammal of this fauna, and must have existed in herds.

BATHMODON MOLESTUS, *sp. nov.*

Established on remains of one species and probably respresented by those of others in possession of the expedition. The teeth differ in several important respects from those of *B. radians* and *B. simus*. Thus the canine is quite compressed in the coronal portion, and is narrow triangular in section, the narrow base of the triangle being concave; that is, the section of a strong groove, which is bounded by a sharp edge on each side. The edge proper of the crown is also duplicated by a ridge of the enamel, which joins it at an acute angle. The last upper molar is characteristic in its wide crown, the posterior usually transverse crest being curved so as to represent the segment of a circle, the convexity posterior. The ramus of the lower jaw is very slender. The posterior inferior molar is large, and has subequal transverse crests. The posterior cingulum, which descends from the external angle, is moderately developed on both of the crests.

In a young specimen of this or an allied species of *Bathmodon*, the deciduous tooth which is replaced by the last premolar has two external crescents; an interesting point of resemblance to the *Perissodactyle* ungulates.

Measurements.

	M.
Width of anterior crest of last inferior molar	.023
Width of anterior crest of superior molar	.039
Length of superior molar	.029
Antero-posterior diameter of crown of canine	.022
Transverse diameter of crown of canine	.013
Depth of mandible at last lower molar	.050

BATHMODON LOMAS, *sp. nov.*

The very numerous remains of the genus *Bathmodon* obtained are referrible to several species, as indicated especially by the teeth. The present form is characterized among other points by the form of the last inferior molar. The anterior crest is much more elevated than the posterior, with its inner apex almost a cone, with anterior, thick, revolute border. The usual oblique cingulum descends from the outer apex forward. The longitudinal ridge connecting the crests is low but distinct, while the posterior cingular ridge is remarkably large. This, which constitutes one of the specific marks, is extended horizontally so as to form a broad ledge, whose border is a segment of a circle. Enamel roughened with five ridges on all the external surfaces. Tooth well worn by prolonged use.

Measurements.

	M.
Length of crown	.041
Width of crown anteriorly	.027
Width of posterior crest	.022
Elevation of posterior crest	.011
Elevation of anterior crest	.024

BATHMODON ELEPHANTOPUS, *sp. nov.*

The most abundant species of the New Mexican Eocene formation, and of the largest size, exceeding in this respect both the *B. simus* and *B. molestus*. I describe at present the last molars of both superior and inferior series. The former is a transverse oval, slightly swollen on the posterior border external to the middle point. The two crests are parallel, the anterior as usual curving round to the inner extremity of the shorter posterior, and leaving a wide interval between them. The posterior is not divided, but is, elevated at the extremities. Anterior cingulum strong, posterior obsolete, excepting on the external border, where it sends a low ridge to the elevated extremity of the anterior crest. Exteroanterior to this ridge is a shallow fossa. Enamel very slightly rugose. The posterior lower molar exhibits a great disparity of elevation of the crests, the anterior being high, and terminating on the inner side in an elevated cone. The con-

necting ridge is low, and there is only a trace of a descending posterior cingulum on the posterior crest.

Measurements.

	M.
Width of last superior molar	.040
Length of last superior molar	.030
Length of last inferior molar	.039
Width of last inferior molar	.026
Elevation of posterior crest of inferior molar	.015
Elevation of anterior crest of inferior molar	.025

A remarkably fine skeleton of a species of this genus, discovered by my friend and assistant, William G. Shedd, exhibits characters heretofore only inferential, and demonstrates the correctness of a number of positions heretofore based on a few fragmentary bones. The feet exhibit proboscidian characters throughout. They are very short and plantigrade, and there are five digits on the hind foot. The calcaneum is recurved inward, and the astragalus flat above. The navicular is transverse and very thin, while the cuboid is subequilateral. The metatarsals are short, and the phalanges much wider than long. The cranium remarkably resembles that of a carnivorous animal in its massive expanded zygomas and huge canine tusks. It differs remarkably from this type, and shows its affinity to *Uintatherium* in the broad plane of the upper cranial wall, with overhanging marginal crests for the attachment and protection of the temporal and neck muscles. These crests do not support horns. The muzzle is contracted at the diastema, thus rendering more prominent the ridges which mark the position of the alveoli of the tusks. The latter are directed downward, giving the profile the pick-ax-like form of that of *Uintatherium*, though more robust in its proportions than the latter. The length of this skull is 19 inches; the width at the zygomas 13.

PHENACODUS PRIMÆVUS, Cope.*

Char. gen.—The genus *Phenacodus* was first recognized by the writer in a posterior inferior molar of a mammal of about the size of a hog, of unknown affinities, which was named *P. primævus*. Specimens of the same species, embracing the dentition of both jaws, having been procured in the Eocene of New Mexico, I am prepared to add to the characters of the genus.

There are three molars in each jaw, and the specimens include two premolars, which form a continuous series, as in *Achænodon*. There are four principal tubercles on the inferior molars and sometimes a third small one between the posterior pair, always on the last one, which is, however, not largely developed. The first inferior premolar presents a broad heel, a double medium tubercle, and an anterior tubercle, (in *P. primævus*.) The crowns of the superior molars are low and broad, and support numerous tubercles; these are low and vary in number, but there are two near the external border which are quite constant. They have general resemblances to those of hogs, bears, and monkeys. The first true molar is broader than long, and there are no diastemata between it and the premolars, or between the latter, which are quadri-, and tri-cuspid, respectively. The forms of these teeth are entirely different from those of the corresponding teeth in *Elotherium*.

Char. specif.—The posterior molar of the left side is wide in front and regularly oval in posterior outline, and has two equal anterior and three unequal posterior tubercles. One of the posteriors is situated near the middle of the outer side, and is separated from the adjacent anterior by a deep groove. The corresponding inner tubercle is more posterior; anterior tubercles low, trihedral, and connected by a shelf-like cingulum across the front of the tooth; rudimental cingula on outer side of crown. The penultimate molar has three tubercles on the posterior border; and a deep fissue, corresponding to that of the last molar, separates one of them from the anterior tubercle.

Measurements.

	M.
Length of last molar	.015
Width { anteriorly	.011
Width { between two posterior tubercles	.005
Elevation of anterior cusp from base	.008
Width of penultimate molar behind	.010

From the same locality as the preceding species.

PHENACODUS OMNIVORUS, *sp. nov.*

Superior molar with low and broad tubercular crown, with outline of base parallelogrammic, with one end oblique; the oblique end with two principal low tubercles,

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which form the extremities of two series of similar ones, some of which arise from the strong cingulum which forms part of the summit of the crown.

Char.—Molar without cingulum on the (?) outer side only; elsewhere very strong and crenate, at one point rising into a stout, low tubercle. The largest tubercle is near this, on the inner summit of the crown, and is connected with the larger outer by a low, broad tubercle. A smaller one intervenes between the cingular tubercle and the smaller external. The outer tubercles low and broad, a smaller one opposite the internal between them in the position of a cingulum. Enamel coarsely rugose.

Measurements.

	M.
Transverse diameter	.014
Longitudinal	.010
Distance between apices of inner and outer tubercles	.007
Elevation of cingulum	.004
Elevation of outer cusp	.005

The tooth described is about the size of the posterior inferior molar of the black bear, (*Ursus americanus.*)

PHENACODUS SULCATUS, *sp. nov.*

Represented especially by the molar tooth corresponding to that above described under the head of *P. omnivorus*, in good preservation. It is a species considerably less than half the size of the one just named, and presents several important differences of structure. Of the two outer tubercles, one is very small, and there is a third adjacent to the larger, produced by the enlargement of the cingulum. As in *P. omnivorus*, the cingulum extends entirely round the remainder of the crown, and is tubercular on the side of the least outer tubercle. The inner tubercle is connected with the larger outer by an intermediate of elongate form, so that the series when worn down resembles the transverse ridge of the superior molar of *Hyposyus*, and which is separated by a groove from the cingular ridge on each side.

Measurements.

	M.
Transverse diameter	.008
Longitudinal diameter	.006
Distance between apices of inner and outer tubercles	.004
Elevation of cingulum	.002
Elevation of outer cusp	.003

Size similar to that of the corresponding tooth of a *Coati*.

OXYÆNA LUPINA, *gen. et sp. nov.*

Represented by a portion of the cranium, which includes the greater part of the dentition. The generic characters are, three premolars and four molars above and below; lower premolars with anterior cone and posterior cutting heel; last premolar and all the molars of the superior series with an internal heel; the last molar transverse; first and second upper molars with an anterior cone and posterior cutting lobe; the penultimate with two anterior acute cones, the posterior forming a sectorial edge with the posterior lobe; last superior molar trenchant.

Mandibular dentition, I., 0; C., 1; P. M., 3; M., 3; the canine teeth directed forward and upward without intervening incisors. First premolar one-rooted; second and third consisting of an anterior elevated cone, and posterior heel, which is elevated in the middle.

The first true molar is nearly similar, with the posterior tubercle sharp edged. Last two molars with an anterior elevated portion and small low heel; the former consisting of three acute tubercles, of which the largest or interior forms with the anterior a sectorial blade oblique to the axis of the mandibular bone.

This genus has one less molar with double median cones than *Prototomus*. It is one of the flat-clawed group, of which two forms have already been described, *Mesonyx*, Cope, and *Synoplotherium*, Cope, which present in their dentition a nearer resemblance to the genus *Hyænodon* than to any other of later age. It differs from both the genera named in having only six molar teeth, and the triangular type of inferior sectorial teeth has not yet been obtained among them. The *O. forcipata* is the larger species; the smallest one described by me is the *Oxyæna morsitans*. In *Stypolophus brevicalcaratus*, I find three sectorials of the form described instead of two only.

Char. specif.—The posterior cutting lobes of molars 1 and 2 elevated and rather obtuse, that of molar 3 lower and more acute. Molar 2 has a well-marked anterior tubercle; molar 4 consists of an outer cutting edge and inner cone. The inner tubercle of molar 3

is smaller than in the three teeth preceding. First lower premolar well developed with one root. Enamel of all the teeth, especially of the canines, rugose.

This species is allied to those of the genus *Pterodon*.

Measurements.

	M.
Length of four posterior superior molars	.055
Length of first true molar	.016
Width of first true molar	.015
Length of second true molar	.016
Width of third (transverse) molar	
Length of five anterior inferior molars	.054

This species is intermediate in size between the *O. forcipata* and *O. morsitans*. The penultimate inferior molar differs from that of both these species in the much weaker development of the internal lateral tubercle and more obtuse anterior tubercle; in *O. forcipata* the blade is continued on the front of this tubercle.

Two specimens embracing five series of teeth have been examined by the writer; the measurements given are those of the smaller.

OXYÆNA MORSITANS, *sp. nov.*

The genus of flesh-eating mammals, described in 1872 under the name of *Stypolophus*, presents a type of dentition which is further illustrated by the present addition of new species much larger than any hitherto known to possess it. Those described are in the order of size: *S. insectivorus*, *S. pungens*, and *S. brevicalcaratus*, Cope. The present new species is twice the bulk of the last. It is represented by broken mandibles with molars and canines of two specimens, and part of the maxillary dentition of a third. The molar, which is typical of the genus, in its subtriangular basis supporting three elevated cusps, and a short heel, is evidently functionally the sectorial, whatever its homological relations may be. In the present instance, the inner posterior cusp is much reduced, while there is a small additional cusp on the front of the anterior near its basis. The trihedral outer posterior forms a cutting edge with the large outer anterior, which is produced forward. A posterior molar exhibits a corresponding tricuspidate portion, and a more elongate heel, with acute circumference. In a premolar, the posterior heel becomes trenchant and median. The canine is very stout and compressed at basis. The enamel in all the teeth is more or less rugose.

Measurements.

	M.
Length of base of crown of sectorial tooth	.014
Width of base of crown of sectorial tooth	.009
Elevation of principal cusps	.015
Elevation of inner posterior cusps	.007
Length of basis of posterior molar	.012
Width of basis of posterior molar	.007
Length of heel of posterior molar	.005
Elevation of principal cusps	.011
Elevation of anterior cusps	.006
Long diameter of canine at base	.012

The maxillary series belongs to a still larger animal. The sectorial presents the same form as that of the mandibular series, and is more robust in form than in existing *Carnivora*. The section of the middle crests is very convex on the inner side, so that the shear is oblique. The heel is small and low. The premolar preceding has a large, broad heel. In another premolar, the heel supports a median crest, while the anterior part of the crown is a slightly-compressed cone, with a small tubercle at the anterior base. Other specimens indicate that this species lacks the inferior incisor teeth.

OXYÆNA FORCIPATA, *sp. nov.*

Char. specif.—Mandibular rami robust and deep, with the symphysis short, and the chin contracted. The canine tooth forms a vertical oval in section. The first one-rooted premolar is a stout tooth; there is no anterior basal tubercle on the second and third premolars, but a distinct one on the first true molar. There is a small tubercle at the base of the anterior lobe of the last or second sectorial molar. This tooth is larger than the penultimate. The enamel of all the teeth is quite rugose, although they are well worn by use.

Corresponding characters are exhibited by four specimens of this species, one of which includes portions of the upper jaw. All the bones are particularly massive, and there is a high parietal crest, a fair indication of the size of the temporal muscles.

Additional specimens of the *Oxyæna morsitans*, Cope, show that it differs in the reduced size of the sectorial molars, and the very small first premolar, which is quite rudimental.

Measurements.

	M.
Length of inferior dental series	.103
Depth of ramus at last molar	.040
Depth of ramus at second premolar	.030
Diameter of canine tooth	.019
Length of premolar series	.035
Length of base of penultimate molar	.016
Length of base of last molar	.019
Width of base of last molar	.012
Elevation of crown of last molar	.019
Length of superior last molar	.020
Width of superior last molar	.013

This animal differs in specific characters from the Wyoming carnivores, already referred to, in the greater robustness of all its parts. From *Synoplotherium lanius*, it also differs in the regular increase backward in the size of the molars. In the Wyoming species the penultimate is largest in the lower jaw.

The fragments of the *Oxyæna forcipata* are as large as corresponding parts of the jaguar.

PACHYÆNA OSSIFRAGA, *gen. et sp. nov.*

Char. gen.—Established on a single superior molar tooth of a large carnivore, apparently allied to the group of flat-clawed *Carnivora*. It is either the last premolar or first true molar. It is characterized by the absence of the cutting edge seen in the allied genera, and its replacement by a conic tubercle.

The principal lobe is also a cone, and the inner one a perfect cone, a little less elevated than the principal one.

Char. specif.—Crown with well-developed anterior and posterior basal tubercles; no cinguli, either internal or external. Enamel slightly rugose.

Measurements.

	M.
Length of crown	.020
Width of crown	.018
Elevation of anterior basal tubercle	.006
Elevation of central cone	.011
Elevation of interior cone	.010

This is the largest carnivore yet observed in this formation, and of peculiar character; its structure indicating a diet not purely carnivorous.

PROTOTOMUS VIVERRINUS, *gen. et sp. nov.*

Char. gen.—Three true molars in the maxillary bone; premolars compressed, the last of the upper series triangular in form; each angle enlarged; the center of the crown with a compressed conic tubercle. First and second true molars triangular, with a tubercle at each angle, and two adjacent cones in the center. The tubercle of the posterior angle forms a slight sectional edge with the posterior of the central pair. Last (third molar) transverse, with a median cone. Supposed mandible with the posterior two molars tubercular; the anterior tubercles similar to the posterior.

This genus is evidently allied to the *Viverridæ*, differing from *Viverra*, so far as known, in the simple character of the last two inferior molars. From *Limnocyon* it differs, according to Professor Marsh's descriptions, in possessing three instead of two superior true molars, or, if we include with these the last premolar, as does Professor Marsh, four instead of three. According to Professor Marsh, the tubercular molars in his *Vulpavus* are generally similar to those of the existing genus *Canis*. *Prototomus* presents the number of superior molars seen in *Amphicyon*.

Char. specif.—The *P. viverrinus* is established on a considerable part of the cranium and skeleton of one individual in good preservation. The last upper premolar is triradiate, having concave and subequal sides. The first molar is as broad as long, and is triangular, presenting a right angle outward and forward.

The second molar is broader than long, and presents an acute tubercle on the anterior border between the inner and anterior median cones. There is a tubercle at the inner and outer extremities of the base of the last molar. No cingulum on the posterior or outer sides of the last premolar. External cones of the last two inferior molars subcrescentic in section; anterior inner obsolete; posterior inner prominent.

Measurements.

	M.
Length of last five molars	.024
Length of true-molar series	.013
Length of last premolar	.006
Width of last premolar	.005
Length of penultimate molar	.004
Width of penultimate molar	.003
Width of last molar	.004
Length of last two inferior molars	.009

About the size of the domestic cat.

PROTOTOMUS INSIDIOSUS, *sp. nov.*

Represented in the collections of the survey by parts of the maxillary bone and both mandibular rami with teeth. The species is much less than the preceding, and differs materially in the forms of the teeth. The two anterior tubercles of the tubercular molars are similar and approximated; the posterior slightly divergent, and on the last tooth inclosing a third of small size. The last premolar has a broad heel and stout anterior cone, but no anterior tubercle. The tooth immediately preceding is much smaller, and also possesses a heel. The mandibular ramus is particularly slender, and the angle is not inflected.

Measurements.

	M.
Length of last two inferior molars	.0060
Length of last molar	.0034
Width of last inferior molar	.0020
Depth of ramus at last inferior molar	.0045
Length of last premolar	.0030
Elevation of last premolar	.0025

PROTOTOMUS JARROVII, *sp. nov.*

This *Carnivore* is of considerably larger proportions than either of the preceding. It is readily recognized as pertaining to the same genus by the identical form of the last two inferior molars, which are quite different from the corresponding ones in *Oxyæna* and other genera. These indeed, with the portion of the mandibular ramus which supports them, are the only well-preserved remains of this animal as yet in our possession. They indicate an animal of the size of the gray fox. In the last molar, the inner anterior tubercle is double, though low and obtuse. It differs from that in the species last enumerated in the presence of only two tubercles on the posterior portion of the crown instead of three, one being terminal and the other on the middle of the outer side. There are but two on the posterior end of the penultimate tooth, and all are low and unconnected excepting by the distinct rim of the crown. The center of the crown is thus concave. The rim is interrupted by notches between the tubercles on the outer side. No cingulum on inner, a weak one on outer side. Enamel smooth.

The form of the molars is rather stout, and the ramus is thick and not deep, and with broad, simple, lower border below the molars.

Measurements.

	M.
Length of last lower molar	.0070
Width { anteriorly	.0045
Width { posteriorly	.0020
Width of penultimate behind	.0050
Elevation of anterior cusp of last	.0030
Depth of ramus at last molar	.0140

This species is dedicated to my friend Henry C. Yarrow, M. D., to whom was committed the charge of that party of the survey to which I was attached, and to whose zeal in the cause of the natural sciences the success of the special expedition is largely due.

LIMNOCYON PROTENUS, *sp. nov.*

A civet-like Carnivore represented by one entire and a portion of the other mandibular ramus, with teeth well preserved, agrees in generic characters with the species referred by Professor Marsh to his genus *Limnocyon*, but differs from them all in its superior size. The molars are $\frac{4}{4}$, but the first molar is like the premolars of the *Canidæ*, except in a slight widening of its posterior basis by the development of a broad cingulum on the inner side and round the basal lobe behind. From this point it extends forward on the outer side to the beginning of the anterior basal lobe, and there

ceases. The second molar has the anterior portion elevated, supporting three cusps and a large heel, with lateral and sub-median cutting edges. The last molar is smaller, elongate, oval, and two-rooted, with marginal posterior, intermarginal external, and two anterior tubercles, of which the inner is bifid. The ramus is slender, and the symphysis elongate. The angle is not incurved. First premolars one-rooted.

Measurements.

	M.
Length of dental series	.0680
Length of four premolars	.0340
Length of first molar	.0105
Length of second molar	.0100
Width of second molar	.0055
Length of third molar	.0080
Width of third molar in front	.0040
Depth of ramus at third premolar	.0130
Depth of ramus at last molar	.0150

ALLIGATOR CHAMENSIS, *sp. nov.*

Represented by portions of the mandibular arch of a small crocodilian resembling in some respects the *A. heterodon* of the Wyoming beds. The posterior teeth have the same short, expanded, sessile, bean-shaped crowns, with a median longitudinal ridge, and more delicate lines radiating close together from it to the border of the crown. The anterior teeth differ in being cylindric instead of compressed. There is a large canine preceded and followed by teeth of much smaller size.

Measurements.

	M.
Length of symphysis	.019
Length of alveoli of six teeth from symphysis	.022
Width of ramus just behind symphysis	.010
Long diameter of posterior tooth	.005

The specimens selected as type is one of the smallest. The surface of the bones is roughened with pits.

PLASTOMENUS LACHRYMALIS, *sp. nov.*

The largest species of the genus, and abundantly represented in the Eocene of New Mexico. The costal bones are rather finely punctate, the posterior as well as the anterior. The anterior costal bones are crossed by numerous ridges from side to side obliquely; the obliquity increasing posteriorly. On the posterior bones, they are broken into vertical bars, separated by considerable intervals, and of linear form. The posterior costals reach a thickness of $0^{m}.006$ and a width of $0^{m}.025$.

The pitting of the posterior part of the carapace distinguishes this species from the *P. œdemius.*

PART II.

In addition to the investigations pursued in the regions already indicated, and of which some of the new species have been described, it may be stated that a careful examination was made of the extensive lacustrine deposits in the valley of the Rio Grande.

These deposits are supposed to commence to the northward of Taos, N. Mex., and continue to an unknown distance southward, certainly at least fifty miles beyond Santa Fé, and occupy that portion of the valley between the Rocky Mountains in the east and the Jemez range in the west, and have been stated as late Tertiary, but without special determination or co-ordination with the other known lacustrine formations of this continent.*

Abundant material having been obtained by the party, it is easy to determine the fauna, whose remains are entombed in it, to be a part of that already described by Dr. Leidy and the writer as occurring in Dakota and Colorado under the name of Pliocene. This conclusion is indicated by the presence of the genera *Hippotherium*, *Protohippus*, *Procamelus*, *Cosoryx*, and *Merychippus*, and known Pliocene species of other genera, among which may be mentioned *Canis*, *Aceratherium*, &c. In addition to species already known, a number new to science were obtained, of some of which descriptions are here given.

MARTES NAMBIANUS, *sp. nov.*

Represented by a mandibular ramus, which supports three teeth. The anterior blade of the sectorial is rather obtuse.

* The new species described from the valley of the Rio Grande were discovered from August 20 to September 1, 1874.

The first premolar is one-rooted; the second and third are without posterior coronal lobes, but exhibit small basal lobes, both anterior and posterior. The anterior of the second is rather elevated, and the entire crown is directed obliquely forward. Canine compressed; mental foramina below the second and third premolars.

Measurements.

	M.
Length of three premolars	.006
Elevation of anterior lobe of sectorial	.002
Depth of ramus at anterior lobe of sectorial	.003

This species is of smaller size than the *M. mustelinus*, Cope, and the sectorial tooth less elevated and trenchant.

COSORYX RAMOSUS, *sp. nov.*

Char. gen.—Inferior molars prismatic, $\frac{3}{3}$; the premolars all sectorial, last with short branch-crests. Molars with basal intercolumnar tubercles. Horns superciliary, solid, branched. This genus was indicated by Dr. Leidy from a horn of the species known to him, the *Cosoryx furcatus*, from the Pliocene beds of the Niobrara. The same or a similar species has left abundant remains in the Santa Fé marls, and, in connection with the more numerous *C. ramosus*, has enabled me to determine the dental and other characters of the genus. After a careful examination of the horns of these species in my possession, those of eighteen individuals (at least I find that of ten where the basal portion is preserved) the beam has been broken off and reunited by anchylosis in six. In most of these the spot is marked by a ring of exostosed tuberosities, like those constituting the burr of the deer's horn. On a specimen of this character, pertaining to a third species, Professor Leidy based his *Cervus warrenii*, which may now be called *Cosoryx warrenii*. It is abundant in the Santa Fé marls.

The fracture has taken place in every instance at a point as far above the frontal bone as the burr of deer is situated, and is irregular in outline, higher on the one side than the other. In some of the specimens the smaller antlers are also broken, and exhibit a similar burr, but the terminal portion is usually lost. In one specimen, a broken antler is anchylosed in the usual manner of overlapping ends. The horns are solid, the center having a narrow, spongy axis. The surface is dense and marked by arterial grooves, but not pierced by noticeable foramina.

It is evidently a question whether this genus should be referred to the hollow or solid-horned *Ruminantia;* to the *Bovidæ*, or *Cervidæ*. The horns might be regarded as those of deer were it not for the occasional specimens without burr, while the teeth are both cervine and bovine. We way here draw such inferences as we can respecting the nature of the covering of the horn. That the fractured beam should not be lost indicates the presence of some kind of covering to retain it. That this covering was not horny is probable from the fact that the horns are branched, a structure impossible to the *Bovidæ*, since antlers effectually prevent the usual mode of increase of horn by additions at the base and removal at the extremity. That such covering protected arteries, which aided in the production of burrs, is also probable. We may thus believe it to have been dermal like that of the giraffe, or the *Antilocapra*, at the period of immaturity of its horny sheath.

It may be concluded, then, that the genus *Cosoryx* represents the ancestral type of the *Cervidæ*, and explains the origin of the remarkable type of horns of that family as follows: Ruminants with fixed horns of structure more dense and brittle than others of the same type, in their annual combats at the rutting-season, very frequently broke the beams off not far above the base. The usual location of nutrition followed, which, being annually repeated, became as periodical in its return as the activity of nutrition of the reproductive system. This activity ceasing, the horn, being dense, lost its vitality, the more so as the normal covering would have already perished in its distal portions. The natural consequence, the separation of the dead from the living bone by suppuration, would follow. This process would, however, probably require a longer time for the establishment of its periodical return than the fracture and attachment of the existing horn.

This appears to be the only explanation of the origin of the phenomena exhibited by the horns of the *Cervidæ*, and is suggested by the specimens of *Cosoryx* to be described.

Char. specif.—This species is larger than the *C. furcatus*, Leidy, and differs from the *C. warrenii* in possessing two antlers instead of one, of which the first is given off at a point much farther from the base than in that species.

The beam near the base is curved a little inward, and is semicircular in section, the outer face being slightly concave, the inner very convex. The base is situated a short distance within the free superciliary border. The beam becomes more cylindric, and then, expanding in a fore and aft direction, gives off an antler at right angles nearly parallel to the cranial axis. At a distance little over half the elevation of the first antler, the beam gives off a second in a plane tranverse to the axis of the skull. The terminal portion of the beam is cylindric, curved, and acute at the apex.

Mandibles, with teeth of two species of this genus, were found, the smaller of which occurring with the other portions of *C. furcatus*, belong to it. The larger differs in the elevation of the intercrescentic column of the first molar, which is worn into a loop at ordinary maturity; this may, however, be but an individual variation. The diastema is long and the ramus of that point quite slender.

Measurements.

	M.
Long diameter of base, No. 1	.016
Long diameter of base, No. 2	.020
Elevation of first antler from base, No. 1	.080
Elevation of second antler from first, No. 3	.042
Length of terminal part of beam, No. 4	.005
Length of molars 2–5, No. 5	.037
Length of molars 4–5, No. 5	.022
Length of fifth molar	.012
Width of fifth molar	.006

COSORYX TERES, *sp. nov.*

Established on the connected frontal bones, supporting the horns of one specimen, and represented by portions of horns of two others. The former individual is larger than any one belonging to the other species, and the species is doubtless the largest of the genus. The horns stand above the posterior part of the orbit, which excavates its base, and presenting a considerable face, descending into the temporal or zygomatic fossa. There is no free superciliary rim outside of the base as in *C. ramosus*, Cope. The section of the beam near the base is a regular oval; the long axis directed longitudinally and a little outward in front. The beam is erect, with a slight curvature outward at the inner base only. So far as preserved, it does not branch, but may do so in its distal portion, which is lost. The tissue is more spongy interiorly than in the other species; supraorbital foramen far within the superciliary border.

Measurements.

	M.
Outer width between bases of horn-cores	.112
Inner width between bases of horn-cores	.055
Width of temporal fossa behind horns	.053
Long diameter of horn-core	.028
Short diameter of horn-core	.021
Length of part preserved	.033

This species was as large as the *Antilocapra americana* of the plains.

HESPEROMYS LOXODON, *sp. nov.*

An entire mandibular ramus, with all the teeth preserved, was found in the same deposits as the preceding species. Molars subequal, short-crowned; triturating surface sigmoid. The apices of the sigma on the inner side tubercular, and anterior to the outer apices. First molar with an additional transverse crest in front. Incisor compressed; outer angle of enamel face rounded smooth. Molar series oblique, rising anteriorly.

Measurements.

	M.
Length of molar series	.0050
Length of first molar	.0018
Depth below last molar, (inner side)	.0030
Depth below first molar	.0045
Depth of incisor	.0015
Depth at diastema	.0027

PANOLAX SANCTÆFIDEI, *gen. et sp. nov.*

Char. gen.—Molars prismatic, transverse, except the first and last; each divided by a plate of enamel extending transversely from the inner side. Anterior molar longitudinal; posterior molar composed of two columns.

This genus is represented by numerous teeth and portions of the cranium. It evidently belonged to the *Leporidæ*, and is allowed to both *Lepus* and *Palæolagus*. As the teeth are mostly separate, it is not easy to determine which is the posterior and which the anterior molar. Judging by the analogy of the known species, the determination as here made is correct; should the relations be reversed, the species will be referred to *Palæolagus*.

Char. specif.—The teeth are curved, the convexity inward. Inner face grooved, the groove occupied by cementum, the outer border compressed either without or with

very shallow groove. First molar with triturating surface twice as long as wide, with an entering loop of enamel on the inner side anteriorly narrower. Last molar as wide antero-posteriorly as transversely, the shaft curved backward, the posterior column sub-cylindric half the diameter of the anterior.

Measurements.

		Inch.
Diameter of middle molar	antero-posterior	.093
	transverse	.107
Diameter of first molar	antero-posterior	.140
	transverse	.062
Diameter of last molar	antero-posterior	.100
	transverse	.065
Length of crown of last molar		.250

This species is about the size of the northern hare.

CATHARTES UMBROSUS, *sp. nov.*

Represented by numerous portions of nearly all parts of the skeleton, in excellent preservation. The beak from the frontal bone to near the apex is preserved; it displays the depression just anterior to the nares, which marks the anterior boundary of the cere. The culmen is nearly horizontal to just beyond this mark, and then exhibits a gradual decurvature to the apex. The beak is strongly compressed, and the tomia strongly decurved, forming an open festoon, whose middle point marks one-fourth the length of the beak from the nares. The latter are directed obliquely downward and forward, narrowing anteriorly and having a prominent inferior bounding ledge.

The mandible is weak, the symphisis-marking on half the length of the beak from the anterior angle of the nares.

The bones of the anterior extremities exhibit large and powerful proportions, as compared with the posterior, appropriately to capacity for sustained flight. The head of the humerus is much compressed, and the articular face is nearly divided into two by the deep bicipital groove. The head of the femur is small, and the rotular face a wide and deep groove.

The tibia is slender, the shaft much compressed, with a prominent ridge. The cnemial crest is short, and not produced downward on the shaft. The distal posterior bridge is narrow and oblique. The tarso-metatarsus has a strong exterior crest, which constitutes half the width of the shaft.

Measurements.

	Inch.
Length of beak from base of culmen, (axial)	1.90
Length of beak from cere to apex, (axial)	1.20
Depth of beak at culmen	.57
Depth of premaxillary at festoon	.75
Length of symphysis	.60
Length of nares	.35
Width of palate at festoon	.50
Width of head of humerus	1.35
Width of condyles	1.13
Width of distal end of femur	.94
Width of head of tibia	.81
Width of condyles of tibia	.66
Width of condyles of tarso-metatarsus	.75
Length of a first phalanx	1.12
Length of seven sacral vertebræ	1.87
Length of two dorsal vertebræ	1.12
Depth of a dorsal vertebra, (total)	.93
Depth of a dorsal vertebra to roof of arch	.44
Depth of centrum of roof of arch	.25
Width of centrum of roof of arch	.32
Length of two cervical vertebræ	1.12
Depth of two cervical vertebræ to apex of neural spine	.44
Depth of articular face of centrum	.17
Width of articular face of centrum	.25

APPENDIX GG.

ANNUAL REPORT OF MAJOR J. W. BARLOW, CORPS OF ENGINEERS, FOR THE FISCAL YEAR ENDING JUNE 30, 1874.

ENGINEER OFFICE, UNITED STATES ARMY,
New London, Conn., August 10, 1874.

GENERAL: I have the honor to present herewith my annual report as engineer-officer of the Military Division of the Missouri on the staff of the Lieutenant-General commanding for the fiscal year ending June 30, 1874.

I am indebted to Prof. T. H. Safford, of the University of Chicago, for the principal portion of the astronomical calculations and a large share of the field-work.

It is to be regretted that the transits used proved inadequate for nice work; but, suspecting this, three independent results for the longitude of Bismarck have been obtained, and our personal equation eliminated. These results not differing largely from each other, either one, or their mean, may be safely taken as a close approximation to the true longitude sought.

Very respectfully, your obedient servant,

J. W. BARLOW,
Major of Engineers.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

EXPLORATIONS AND SURVEYS, MILITARY DIVISION OF THE MISSOURI.

Surveys and explorations have been conducted by the engineer-officers of the several departments, the results of which have usually been forwarded to division headquarters, where they have been compiled for ilitary and geographical purposes.

mAstronomical determinations have formed an important part of these surveys, by which erroneous positions of many points have been corrected.

From this office, by Major Barlow and Professor Safford, were determined the longitude, by telegraph, of Bismarck, on the Missouri River, the present terminus of the Northern Pacific Railroad, and the latitude, by the prime-vertical method, of Bismarck and Fargo. A report in detail of this work is submitted.

The usual work of revising the maps of the military division has been continued during the year. To this end, information has been collected from all possible sources, including railroad and land-office surveys, scouting parties, and expeditions sent out specially to obtain geographical and topographical information.

The following office-work has been completed:

I.—LITHOGRAPHIC PUBLICATIONS.

1. Corrections and additions (office-compilations) upon the War Department map of Kansas, Indian Territory, and Texas.

2. Map of Yellowstone River, from Fort Buford to mouth of Powder River; Captain Ludlow's survey.
3. Map of a part of Indian Territory, vicinity of Fort Sill, prepared by Lieut. Col. J. W. Davidson, Tenth Cavalry.
4. Scout from Fort Russell to North Park and Laramie Plains; General Sheridan's party.
5. Eastern Mexico and a part of Texas, (office-compilation.)

II.—MILITARY RESERVATIONS AND POSTS.

Maps of all the reservations in the division and plans of the posts—about sixty of each—have been constructed to a uniform size of 4 by 7 inches, and carefully drawn, with a view of having them engraved to illustrate the outline-descriptions of posts in the Military Division of the Missouri, being prepared at the headquarters of the division.

The work of engraving these maps on copper-plates by an enlisted man of the Army has been commenced, and an agreement for doing the printing at a moderate expense has been made.

III.—NEW MAP OF WESTERN TERRITORIES.

Authority for continuing the engraving upon stone of the new map of the Western Territories on a scale 1÷2000000 (one sheet of which was published last year) having been suspended, and the draughtsman's time employed upon more pressing matters, but little progress has been made during the season upon that important work. As stated in my last annual report, two additional sheets are nearly ready for the engraver, and, now that recent explorations have added materially to the previous knowledge of the region covered by these sheets, I would respectfully recommend that this office be given the necessary authority to have them completed and engraved.

This map was projected to embrace the territory lying west of a line drawn near the eastern boundaries of Minnesota and Texas, and was to have been engraved in six sheets, each 19 by 25 inches; four of these could readily be completed, making a map about 38 by 50 inches, extending to the western limits of the Military Division of the Missouri. This would be a valuable and convenient map for military and geographical purposes.

Pursuant to Special Orders No. 140, War Department, Adjutant-General's Office, Washington, June 26, 1874, I was relieved from the staff of the Lieutenant-General, and the charge of the office was transferred to Major G. L. Gillespie.

Statement of funds.

Amount on hand June 30, 1873	$510 68
Amount received during year	6,000 00
Amount expended	5,684 12
Amount on hand June 30, 1874	826 56
Amount available July 1, 1874	$2,500 00
Amount desired for fiscal year ending June 30, 1876	10,000 00

DETERMINATION OF THE LATITUDE AND LONGITUDE OF BISMARCK, DAKOTA, AND OF THE LATITUDE OF FARGO, DAKOTA.

The instruments used were, at Du Luth, a transit by Patton & Son, marked U. S. Topographical Bureau No. 1; manifestly an old instrument, but recently repaired. The images given by its telescope were

very bad, so that it became impossible to adjust the wires in the focus with any accuracy. As will be seen by the results, it is an inferior instrument; although, so far as the level of its axis would indicate, it is reasonably good, being very firm in its mechanical construction.

The instrument employed at Bismarck was a Würdemann No. 13. The object-glass was bad, but for the time being was replaced by a better; this latter glass has since been transferred to Patton No. 1. Both instruments have nearly the same focal distance and aperture; about 25 inches and 2 inches respectively. The Würdemann transit gave at first some trouble, from the fact that the eye-piece would slip away from the object-glass, altering the focal distance when the telescope was pointed nearly at the zenith.

No chronograph was used; the observations were of two kinds, eye and ear, by the usual method, combined with signals sent by hand from the chronometers, and star-transits sent telegraphically and noted by the recorders at both ends of the line. The nights when the latter method was employed gave each two results; one from the eye and ear transits, and the other according to the second method. These two results were effected with different personal equations, but were very nearly independent of each other. Although the star-transits served as arbitrary signals also, I do not apprehend that they introduced any new error, as their results for both directions of the current differ very little.

The telegraph-line was in such excellent condition that the wave-time is very small, and masked under the personal equations of sending and receiving signals. The personal equation, $0^s.59$, between Colonel Barlow and Professor Safford was determined by three nights' observations in June, 1874. It has the same sign as the value $0^s.39$ between Mr. MacConnel and Professor Safford, determined by exchange of observers during a series of observations made in November, 1873, to fix the west line of Wyoming Territory; Professor Safford's clock-corrections being smaller than those of the other two observers.

The value $0^s.35$ derived from the star-signals includes a different personal equation for the two recorders. It was obtained by a comparison of the individual nights' results by this method.

The latitude of Bismarck was determined by observations with the transit Würdemann No. 13 in the prime vertical. The transits of the same star across the prime vertical were not obtained; it was preferred to use transits both east and west of the meridian of different stars, but about the same time.

This method has the advantages that each star gives a result; that the operations can be rapidly conducted, and so as to eliminate all instrumental errors. Were the level always upon the axis and a chronograph at hand, it is believed that it would give results of greater accuracy than the zenith-telescope; the more as there is no necessity to include stars not well observed at the fixed observations.

The latitude of Fargo was determined by a few observations made October 13, between flying clouds, to be $46^\circ\ 52'\ 48''$ by the same method. It became completely cloudy after three stars had been observed in the reverse position of the instrument.

* * * * * * *

Latitude of Bismarck, from observations made October 9, 1873, in the—

	Star's name.	No. B. A. C.	E. or W.	T + Δ t		δ	φ'	Remarks
				h. m. s.	h. m. s.	° ′ ″	° ′ ″	
1	ρ Herculis	5886	W.	20 17 3.00	17 19 18.58	37 15 58.1	46 49 6.05	For the rest and metho reduction, Cha uvena Astronomy p. 269.
2	6 Lacertæ	7850	E.	22 15.23	22 25 2.63	42 28 43.3	47 57.63	
3	o Andromedæ	8023	E.	42 41.02	56 7.26	41 38 58.3	47 55.64	
4	θ Herculis	6082	W.	49 36.32	17 51 54.38	37 16 16.8	49 07.21	
5	ζ Andromedæ	52	E.	21 19 13.14	0 10 30.42	37 58 54.9	47 22.88	
6	ι Andromedæ	8229	E.	30 29.68	23 31 57.33	42 34 15.3	39.29	
7	ξ Lyræ	6392	W.	36 19.20	18 40 24.71	37 28 37.2	48 51.00	
8	η Lyræ	6581	W.	52 11.80	19 9 26.95	38 55 58.2	46.12	
9	μ Andromedæ	259	E.	56 59.74	0 49 45.46	37 48 55.0	47 22.76	
10	θ Lyræ	6599	W.	22 4 5.18	19 11 58.58	37 54 44.5	48 48.58	
11	γ Cygni	7022	W.	51 18.64	20 17 41.56	39 51 22.4	48 42.45	
12	τ Andromedæ	502	E.	23 0 33.32	1 33 8.51	39 56 14.6	47 33.19	
13	υ Andromedæ	480	E.	5 48.26	1 29 24.01	40 46 27.2	47 34.26	
14	υ Cygni	7277	W.	17 15.08	20 52 27.92	40 41 3.6	48 36.62	
15	75 Cygni	7544	W.	35 6.80	21 35 13.96	42 42 12.6	48 44.81	
16	γ Andromedæ	628	E.	43 39.96	1 56 9.76	41 43 24.3	47 45.79	
17	16 Persei	871	E.	49 40.78	2 42 37.53	37 47 54 0	47 37.48	
18	6 Cygni	7398	W.	55 50.46	21 12 27.41	38 52 8.1	48 57.71	

Latitude of Bismarck, from observations made October 9, 1873, in the prime vertical.

	log tan z	log sec z	b	A a	C c	φ	Remarks
			″	″	″	° ′ ″	
1	9.8267	0.081	—1.65	—44.22	—3.19	46 48 13.0	
2	9.6089 *n*	0.033	—1.65	+26.78	—6.44	16.3	
3	9.6538 *n*	0.040	—1.10	+29.70	—6.55	17.7	
4	9.8266	0.081	—0.72	—44.21	—7.19	15.1	
5	9.8024 *n*	0.073 *n*	+0.93	+41.81	+7.06	12.7	
6	9.6032 *n*	0.032 *n*	+1.22	+26.43	+6.43	13.4	
7	9.8197	0.078 *n*	+1.26	—43.51	+7.15	15.9	
8	9.7697	0.065 *n*	+1.39	—38.78	+6.93	15.7	
9	9.8081 *n*	0.075 *n*	+1.43	+42.36	+7.10	13.6	
10	9.8054	0.074 *n*	+1.48	—42.10	+7.10	15.1	
11	9.7345	0.056 *n*	+1.86	—35.76	+6.79	15.3	
12	9.7306 *n*	0.055 *n*	+1.93	+35.44	+6.78	17.3	
13	9.6952 *n*	0.048 *n*	+1.96	+32.67	+6.67	15.6	
14	9.6997	0.049 *n*	+2.02	—33.01	+6.69	12.3	
15	9.5962	0.031	+2.12	—26.01	—6.42	14.5	
16	9.6500 *n*	0.040	+2.17	+29.43	—6.55	10.8	
17	9.8087 *n*	0.075	+2.18	+42.42	—7.10	15.0	
18	9.7721	0.065	+2.18	—38.99	—6.93	14.0	

Adopted values:
a—65″.90
c— 5″.97
Latitude, 46° 58′ 14″.6±0″.31

Probable error of 1 observation, ±1″.30 by sums of errors.
±1″.27 by sums of squares

LONGITUDE OF BISMARCK.

Comparison of chronometer.

Chronometer.	Kind of time.	Where used and when.
Bond 279	Sidereal	Du Luth, Minn., September 30 to October 20, 1873.
Adams 3768	Mean	Bismarck, Dak., September 30 to October 20, 1873.
Adams 3768	do	Du Luth, Minn., October 19 and 20, 1873.
Bond 202	Sidereal	Bismarck, Dak., September 30 to October 20, 1873.

Date.	Bond 279.	Adams 3768.	Direction of current.	Mean of 3768.	Bond 202.	Remarks.
1873.	h. m. s.	h. m. s.		h. m. s.	h. m. s.	
Sept. 30	22 0 0.	9 5 20.308	W.	.....	.....	
		20.337	E.	9 5 20.32	21 26 18.98	
Oct. 5	23 3 19.23	9 50 0.	W.	Mean of 279=	22 29 58.31	
	3 19.08		E.	23 3 19.16	.....	
Oct. 6	23 27 21.55	10 10 0.	W.	Mean of 279=	22 54 04.32	
	27 21.53		E.	23 27 21.54	.....	
Oct. 7	22 51 22.36	9 30 0.	W.	Mean of 279=	22 17 57.79	
	51 22.41		E.	22 51 22.39	.....	
Oct. 8	22 25 13.92	9 0 0.	W.	.....	21 51 51.91	Signals received at Du Luth missing.
Oct. 19	22 11 53.45	8 0 0.	.....	.....	.....	
	0 2 11.79	9 50 0.	.....	.....	.....	
		8 0 0.	W.	.....	21 38 56.26	
			E.	21 38 56.25	56.25	
		9 50 0.	W.	.....	23 29 14.86	
			E.	23 29 14.90	14.93	
Oct. 20	0 36 0.00	10 19 39.52	.....	.....	.....	
		10 19 39.52	.....	.....	0 3 06.67	Observed by T. H. Safford.
Oct. 20	23 16 0	.....	W.	.....	23 48 53.50	Observed by Sergt. Becker.
	0 36 0	.....	E.	.....	1 8 53.50	

NOTE No. 1.—Adopted $0^h\ 9^m\ 0^s$ Bond 279 = $0^h\ 41^m\ 53^s.44$ Bond 202.

NOTE No. 2.—No satisfactory determination of wave-time can be obtained from these observations, as they are influenced by irregularities in the rate of the chronometers, and were not chronographically registered. The amount indicated, however, does not exceed 0.01 in the mean.

The signals observed were very numerous, and were reduced to a mean epoch by one or the other chronometer.

For observations of clock-signals and stars.

Observer.	Recorder of clock-signals.	Place.	Time.
Major Barlow	Mr. Freeman	Du Luth, Minn.	Sept. 30 to Oct. 8, 1873.
Do	do	Bismarck, Dak.	Oct. 19 and 20, 1873.
Professor Safford	Sergeant Becker and Mr. W. H. Wood	do	Sept. 30 to Oct. 8, 1873.
Do	do	Du Luth, Minn.	Oct. 19 and 20, 1873.

Method of observing.—On September 30, and October 5, 8, and 19, stars were observed by eye and ear and clock-signals sent and received by telegraph. On October 6, 7, and 20, some stars were observed by eye and ear, and others were observed after the chronographic method, but the times noted at both places by the recorder. These dates give two values for the longitude: the one from the eye and ear observations; the other from the star-signals sent by telegraph. This method was employed chiefly as an experiment, and has given an independent value for the longitude. In order to receive the ordinary clock-signals with accuracy, the mean-time chronometer (Adams 3768) which accompanied Professor Safford was compared with the two sidereal chronometers, with the one telegraphically and with the other by coincidences.

LONGITUDE OF BISMARCK.

Clock-corrections, Du Luth, Minn., September 30, 1873.

Star's name.	Clamp.	*d t*	Remarks.
		s.	
δ Draconis	W.	− 7.88*	The value of *d t* marked with a
β Cygni	W.	− 9.18	isk (*) refers to stars north
ϕ Cygni	W.	− 9.00	north declination.
15 Cygni	W.	− 8.43	
α Aquilæ	W.	− 8.22	
ϵ Draconis	W.	− 9.34*	
3 Ursæ Majoris (Hev)	E.	− 9.23*	
θ Aquilæ	E.	− 9.17	
κ Cephei	E.	− 7.14*	
θ Cephei	E.	− 5.78*	
α Delphini	E.	− 9.25	
ϵ Cygni	W.	−10.38	
υ^2 Ursæ Majoris	W.	−12.25*	
ζ Cygni	W.	− 8.99	
1 Pegasi	W.	10.36	
1 Draconis H	W.	− 6.53*	
β Cephei	W.	− 8.44*	
1 Cephei	W.	− 9.34	
11 Cephei	W.	−13.20*	
Adopted, for 21h 26m	.....	− 9.20	

Clock-corrections, Du Luth, Minn., October 5, 1873.

Star's name.	Clamp.	*d t*	Remarks.
		s.	
γ Delphini	E.	+ 5.47	
32 Vulpeculæ	E.	4.93	
Piazzi XXI, 1	E.	4.96	
ζ Cygni	E.	4.46	
1 Pegasi	E.	4.24	
β Cephei	E.	3.31*	
11 Cephei	E.	4.28*	
16 Pegasi	E.	4.28	
i Pegasi	W.	3.38	
24 Cephei	W.	6.10*	
31 Pegasi	W.	4.46	
δ Cephei	W.	[1.75]	
η Pegasi	W.	4.43	
γ Cephei	W.	3.57*	
τ Cassiopeiæ	W.	4.11	
ψ Pegasi	W.	4.13	
α Andromedæ	W.	3.86*	
γ Pegasi	W.	3.97	
σ Andromedæ	W.	4.44	
κ Cassiopeiæ	E.	4.42*	
ϵ Andromedæ	E.	3.59	
ξ Andromedæ	E.	3.47	
γ Cassiopeiæ	E.	4.66*	
ϵ Piscium	E.	4.24	
Polaris	E.	+ 9.25*	
Adopted, for 23h 0m	.....	+ 4.22	

LONGITUDE OF BISMARCK.

Clock-corrections, Du Luth, Minn., October 6, 1873.

Star's name.	Clamp.	d t	Remarks.
		s.	
θ Aquilæ	E.	+7.66	
κ Cephei	E.	7.50*	
Cephei	E.	6.55*	
α Delphini	E.	7.28	
Br. 2749	W. }	6.47*	
Br. 2749	E. }		
ζ Cygni	E.	5.59	
1 Pegasi	E.	5.81	
β Cephei	E.	4.04*	
ε Piscium	W.	5.99	
β Andromedæ	W.	6.78	
Polaris	W.	5.66*	
STAR-SIGNALS.			
π Pegasi	E.	7.13	
ε Cephei	E.	6.92	
32 Pegasi	E.	6.80	
δ Cephei	E.	6.98	
η Pegasi	E.	6.61	
ι Cephei	E.	8.11	
β Pegasi	W.	6.88	
π Cephei	W.	6.96	
τ Pegasi	W.	6.41	
ν Pegasi	W.	6.64	
B. A. C. 8188	W.	+6.36	
Adopted for 23h 19m by eye and ear observations		+6.48	
Adopted for 23h 19m by star-signals		+6.73	

Clock-corrections, Du Luth, Minn., October 7, 1873.

Star's name.	Clamp.	d t	Remarks.
		s.	
3 Ursæ Majoris (Hev)	E.	.....	
κ Cephei	E.	+0.59*	
θ Cephei	E.	+0.26*	
α Delphini	E.	+0.01	
ε Cygni	E.	−0.20	
32 Vulpeculæ	E.	−0.35	
α Cephei	E.	−1.30*	
γ Pegasi	W.	−0.06	
υ Andromedæ	W.	+0.50	
κ Cassiopeiæ	W.	+0.19*	
STAR-SIGNALS.			
74 Cygni	E.	−0.12	
μ Pegasi	E.	[−1.18]	
14 Pegasi	E.	+0.16	
ι Pegasi	E.	−0.03	
π Pegasi	E.	+0.04	
ε Cephei	W.	−0.49	
32 Pegasi	W.	[+2.28]	
δ Cephei	W.	[−1.54]	
η Pegasi	W.	−0.20	
ι Cephei	W.	−1.09*	
Adopted for 22h 51m by eye and ear observations		+0.06	
Adopted for 22h 51m by star-signals		−0.11	

LONGITUDE OF BISMARCK.

Clock-corrections, Du Luth, Minn., October 8, 1873.

Star's name.	Clamp.	d t	Remarks.
		s.	
θ Aquilæ	W.	+ 2.72	
κ Cephei	W.	+ 1.98*	
39 Cygni	W.	+ 2.52	
θ Cephei	W.	+ 1.89*	
α Delphini	W.	+ 2.07	
ε Cygni	E.	+ 1.73	
32 Vulpeculæ	E.	+ 2.13	
Piazzi XXI, 1	E.	+ 1.60	
ξ Cygni	E.	+ 2.11	
1 Pegasi	E.	+ 2.23	
β Cephei	E.	+ 2.92*	
74 Cygni	E.	+ 2.95	
β Pegasi	E.	+ 2.56	
π Cephei	E.	+ 3.24*	
γ Piscium	E.	+ 2.57	
ν Pegasi	E.	+ 2.52	
B. A. C. 8188	E.	+ 2.04	
γ Cephei	W.	+ 1.88	
τ Cassiopeiæ	W.	+ 2.38	
χ Pegasi	W.	+ 2.00	
α Andromedæ	W.	+ 2.79	
γ Pegasi	W.	+ 2.96	
Adopted, for 22h 25m	.....	+ 2.45	

Clock-corrections, Du Luth, Minn., October 19, 1873.

Star's name.	Clamp.	d t	Remarks.
		s.	
δ Aquilæ	E.	+24.62	
β Cygni	E.	24.99	
o Draconis	E.	25.67*	
73	E.	25.15*	
γ Delphini	E.	24.77	
Br. 2749	E.	23.93*	
61 Cygni, pr	E.	24.79	
ξ Cygni	E.	24.70	
1 Pegasi	W.	25.09	
B. A. C. 7495	W.	24.57	
13 H. Cephei	W.	25.24	
11 Cephei	W.	24.40	
6 Pegasi	W.	25.03	
η Pegasi	W.	25.46	
λ Pegasi	W.	24.72	
μ Pegasi	W.	25.32	
B. A. C. 8026	W.	23.44*	
κ Pegasi	E.	24.26	
ν Pegasi	E.	24.92	
70 Pegasi	E.	24.82	
γ Cephei	E.	25.69*	
ρ Cassiopeiæ	E.	+25.05	
Adopted, for 22h 19m	.....	+24.92	
Adopted, for 0h 2m	.....	+24.82	

LONGITUDE OF BISMARCK.

Clock-corrections, Du Luth, Minn., October 20, 1873.

Star's name.	Clamp.	d t	Remarks.
		s.	
α Lyræ	E.	+ 23.22	I have attempted to improve the instrumental constants without much success. The night's result is less discordant than usual.
γ Lyræ	E.	23.10	
ζ Aquilæ	E.	22.98	
δ Draconis	E.	23.69*	
δ Aquilæ	W.	23.21	
β Cygni	W.	24.14	
σ Draconis	W.	22.92*	
β Cephei	W.	24.34*	
14 Pegasi	W.	24.37	
16 Pegasi	W.	24.17	Adopted d t: eye and ear observations + 23s.64 for 0h 9m; star-signals, + 23s.81 for 0h 9m.
20 Cephei	W.	25.09*	
24 Cephei	W.	23.05*	
χ Cassiopeiæ	E.	23.73	
η Piscium	E.	23.74	
υ Andromedæ	E.	25.52	
STAR-SIGNALS.			
η Pegasi	W.	24.14	(Rate assumed zero. The stars during the night indicate an increase, those from night to night a decrease of dt.)
λ Pegasi	W.	24.00	
μ Pegasi	W.	23.83	
B. A. C. 7984	W.	23.31	
ο Andromedæ	W.	23.63	
1 Cassiopeiæ	W.	23.63	
2 Cassiopeiæ	W.	24.25	
ν Pegasi	E.	[25.42]	
72 Pegasi	E.	24.01	
ι Andromedæ	E.	24.22	
τ Cassiopeiæ	E.	23.30	
ρ Cassiopeiæ	E.	23.42	
85 Pegasi	E.	24.12	
α Andromedæ	E.	+ 23.53	

Clock-corrections, Bismarck, Dak., September 30, 1873.

Star's name.	Clamp.	d t	Remarks.
		m. s.	
B. A. C. 6480	W.	−1 11.57	
ζ Aquilæ	W.	11.55	
ι Lyræ	W.	11.27	
τ Draconis	W.	11.59*	
β Cygni	W.	11.67	
γ Aquilæ	E.	11.57	
ε Draconis	E.	12.36*	
γ Sagittæ	E.	11.68	
27 Cygni	E.	11.77	
28 Cygni	E.	10.97	
29 Cygni	E.	11.36	
κ Cephei	E.	10.65*	
31 Pegasi	E.	11.14	
6 Lacertæ	E.	11.95	
31 Cephei	E.	11.04*	
λ Pegasi	E.	11.42	
π Cephei	W.	11.24*	
γ Piscium	W.	11.29	
τ Pegasi	W.	11.32	
ν Pegasi	W.	−1 11.11	
Adopted, for 21h. 26m		−1 11.42	

LONGITUDE OF BISMARCK.

Clock-corrections, Bismarck, Dak., October 5, 1873.

Star's name.	Clamp.	d t	Remarks.
		m. s.	
25 Camelopardalis, (Hev.) S. P	E.	−1 19.00*	
θ Lyræ	E.	19.29	
β Cygni	E.	19.37	
θ Cygni	E.	19.27	
δ Cygni	E.	19.10	
χ Cygni	E.	19.24	
κ Cephei	W.	19.00*	
γ Cygni	W.	19.32	
41 Cygni	W.	19.29	
α Cygni	W.	19.34	
η Cephei	W.	19.51*	
τ Pegasi	W.	19.39	
ν Pegasi	W.	19.14	
70 Pegasi	W.	19.41	
72 Pegasi	W.	19.44	
γ Cephei	W.	19.93*	
41 H. Cephei	E.	19.41*	
ρ Cassiopeiæ	E.	19.08	
ω Piscium	E.	19.65	
B. A. C. 8374	E.	19.62	
α Andromedæ	E.	−1 19.62	
Adopted, for 22h 30m		−1 19.37	

Clock-corrections, Bismarck, Dak., October 6, 1873.

Star's name.	Clamp.	d t	Remarks.
		m. s.	
β Lyræ	E.	− 1 19.26	
ε Aquilæ	E.	19.30	
25 Camelopardalis, (Hev.) S. P	E.	19.25*	
δ Draconis	E.	19.92*	
ς Aquilæ	E.	19.11	
ι Cygni	E.	19.47	
15 Cygni	W.	19.00	
α Aquilæ	W.	19.24	
ε Draconis	W.	19.44	
ψ Cygni	W.	19.10	
27 Cygni	W.	19.26	
STAR-SIGNALS.			
β Pegasi	W.	19.64	
2 Cassiopeiæ	W.	19.64	
γ Piscium	W.	19.29	
τ Pegasi	W.	19.14	
ν Pegasi	W.	18.92	
8188	W.	[20.14]	
ψ Pegasi	E.	18.87	
85 Pegasi	E.	19.36	
β Cassiopeiæ	E.	18.88	
γ Pegasi	E.	19.10	
o Andromedæ	E.	18.85	
ADDITIONAL POLAR STARS.			
39 Cephei, (Hev.)	W.	21.46*	
γ Cephei	W.	18.80	
6 Ursæ Minoris, B	E.	− 1 19.63*	
Adopted, for 22h 46m by eye and ear observations		− 1 19.22	
Adopted, for 22h 46m by star-signals		− 1 19.18	

LONGITUDE OF BISMARCK.

Clock-corrections, Bismarck, Dak., October 7, 1873.

	Star's name.	Clamp.	*d t*	Remarks.
			m. s.	
β	Lyræ	E.	−1 19.86	
γ	Lyræ	E.	19.43	
25	Camelopardalis, (Hev.) S. P.	E.	19.77*	
δ	Draconis	E.	19.19*	
4	Cygni	E.	20.03	
β	Cygni	E.	19.40	
δ	Cygni	W.	19.41	
α	Aquilæ	W.	19.33	
λ	Ursæ Minoris	W.	17.84*	
33	Cygni	W.	19.93	
κ	Cephei	W.	20.29*	
γ	Cygni	W.	19.44	
γ	Cephei	E.	18.99*	
ψ	Pegasi	E.	20.09	
γ	Pegasi	E.	19.50	
	STAR-SIGNALS.			
δ	Cephei	W.	19.88	
10	Lacertæ	W.	18.96	
13	Lacertæ	W.	18.99	
ι	Cephei	W.	18.97	
β	Pegasi	W.	19.34	
	Br. 3077	E.	18.93	
τ	Pegasi	E.	19.07	
ν	Pegasi	E.	18.88	
70	Pegasi	E.	19.39	
72	Pegasi	E.	− 19.24	
	Adopted, for 22h 18m eye and ear observations		−1 19.66	
	Adopted, for 22h 18m by star-signals		−1 19.19	

Clock-corrections, Bismarck, Dak., October 8, 1873.

	Star's name.	Clamp.	*d t*	Remarks.
			m. s.	
α	Lyræ	W.	−1 19.93	
β	Lyræ	W.	19.98	
R	Lyræ	W.	20.06	
ν	Draconis	W.	19.75*	
η	Lyræ	W.	19.91	
τ	Draconis	E.	20.23*	
ι	Cygni	E.	19.93	
θ	Cygni	E.	20.25	
δ	Cygni	E.	19.59	
α	Aquilæ	E.	− 19.65	
	Adopted, for 21h 52m		−1 19.94	

Clock-corrections, Bismarck, Dak., October 19, 1873.

Star's name.	Clamp.	d t	Remarks.
		m. s.	
α Lyræ	E.	.....	Instruments not yet adjusted.
α Aquilæ	E.	.....	
λ Ursæ Minoris	E.	.....	
θ Aquilæ	E.	−1 20.52	
κ Cephei	E.	20.43*	
39 Cygni	E.	19.93	
θ Cephei	E.	20.79*	
γ Delphini	E.	20.54	
32 Vulpeculæ	W.	20.81	
ν Cygni	W.	20.77	
60 Cygni	W.	20.61	
ξ Cygni	W.	20.72	
ζ Cygni	W.	20.40	
o Cygni	W.	20.80	
B. A. C. 7705	W.	20.88	
24 Cephei	W.	19.20*	
31 Pegasi	W.	20.65	
3 Lacertæ	W.	19.95	
18 Heis Lacertæ	W.	.....	Star's AR. not known.
6 Lacertæ	W.	20.85	
10 Lacertæ	E.	20.44	
13 Lacertæ	E.	21.01	
μ Pegasi	E.	20.77	
B. A. C. 7995	E.	20.14	
o Andromedæ	E.	20.52	
π Cephei	E.	20.84*	
ρ Cassiopeiæ	E.	20.87	
B. A. C. 8345	E.	20.43	
B. A. C. 8374	E.	20.78	
α Andromedæ	E.	20.96	
γ Pegasi	E.	20.85	
B. A. C. 100	W.	21.00	
κ Cassiopeiæ	W.	20.75	
ε Andromedæ	W.	20.75	
ζ Andromedæ	W.	20.66	
ν Andromedæ	W.	−1 20.79	
Adopted, for 21h 39m, at	.....	−1 20.54	
Adopted, for 23h 29m, at	.....	−1 20.72	

Clock-corrections, Bismarck, Dak., October 20, 1873.

Star's name.	Clamp.	d t	Remarks.
		m. s.	
39 Cygni	W.	−1 25.53	
θ Cephei	W.	25.56*	
α Delphini	W.	25.51	
Br. 2749	W.	25.14	
ζ Cygni	W.	25.72	
o Cygni	W.	25.87	
α Cephei	W.	25.79*	
74 Cygni	E.	25.40	
75 Cygni	E.	25.79	
μ Cygni	E.	25.46	
ν Cephei	E.	25.94	
B. A. C. 7631	E.	25.48	
γ Cassiopeiæ	W.	26.45	
ε Piscium	W.	25.79	
STAR SIGNALS.			
τ Cassiopeiæ	E.	25.58	
B. A. C. 8296	E.	25.47	
ψ Pegasi	E.	25.58	
B. A. C. 8345	E.	25.66	
B. A. C. 8374	E.	25.57	
α Andromedæ	E.	25.09	
o Andromedæ	W.	25.49	
ρ Andromedæ	W.	25.84	
B. A. C., 100	W.	26.04	
κ Cassiopeiæ	W.	25.65	
ζ Cassiopeiæ	W.	25.15	
Adopted from eye and ear observations		−1 25.69	
Adopted from star-signals		−1 25.56	
Adopted rate, equal to zero.			

Computation of longitude, eye and ear observations.

Date.	Signals sent and received, reduced to mean time.	Time corrections.	Corrected time.	Difference of longitude.	Personal equation.	Means.
1873.	h. m. s.	m. s.	h. m. s.	m. s.	s.	m. s.
Sept. 30	21 26 18.19	− 1 11.42	21 25 07.56			
	22 00 00.00	− 9.20	21 59 50.80	34 43.24	− 0.59	34 42.65
Oct. 5	23 03 19.15	+ 4.22	23 03 23.37			
	22 29 58.30	− 1 19.37	22 28 38.93	34 44.44	− 0.59	34 43.85
Oct. 6	23 19 17.42	+ 6.48	23 19 23.79			
	22 46 00.00	− 1 19.22	22 44 40.74	34 43.05	− 0.59	34 42.46
Oct. 7	22 51 22.39	+ 0.06	22 51 22.45			
	22 17 57.79	− 1 19.66	22 16 38.13	34 44.32	− 0.59	34 43 73
Oct. 8	22 25 13.92	+ 2.45	22 25 16.37			
	21 51 51.91	− 1 19.94	21 50 31.97	34 44.40	− 0.59	34 43.81
Oct. 19	22 11 53.45	+ 0 24.92	22 12 18.37			
	21 38 56.25	− 1 20.54	21 37 35.71	34 42.66	+ 0.59	34 43.25
Oct. 19	0 02 11.79	+ 0 24.82	0 02 36.61			
	23 29 14.90	− 1 20.72	23 27 54.18	34 42.43	+ 0.59	34 43.02
Oct. 20	0 09 00.00	+ 23.64	0 09 23 64			
	23 36 06.56	− 1 25.69	23 34 40.87	34 42.77	+ 0.59	34 43.36
		STAR-SIGNALS.				
Oct. 6	23 19 17.42	+ 6.73	23 19 24.15			
	22 46 00.00	− 1 19.18	22 44 40.82	34 43.33	− 0.35	34 42.98
Oct. 7	22 51 22.39	− 0.11	22 51 22.28			
	22 17 57.79	− 1 19.19	22 16 38.60	34 43.68	− 0.35	34 43.33
Oct. 20	0 09 00.00	+ 23.81	0 09 23.81			
	23 36 06.56	− 1 25.56	23 34 41.00	34 42.81	+ 0.35	34 43.16

Final result for longitude of Bismarck, Dak.

Bismarck west of Du Luth observatory.

Date of observations.	Mean result.	Observers.
	m. s.	
September 30 to October 8, 1873	34 43.30	T. H. Safford, at Bismarck; J. W. Barlow, at Du Luth.
October 19 and 20, 1873	34 43.21	J. W. Barlow, at Bismarck; T. H. Safford, at Du Luth.
Star-signals	34 43.16	
Final mean	34 43.22	

The observatory at Du Luth was, by communication of Thomas Allen, esq., assistant engineer in charge of harbor improvements—

8,458.27 feet north of lake-survey north base.
6,370.45 feet west of lake-survey north base.
Or, 2,123.48 yards west of lake-survey north base.

And north base is $1^h\ 0^m\ 6^s.07$ west of Washington by lake-survey determination.

Assuming 46° 48′ as the latitude of the point half-way between the Du Luth observatory and north base, we have, by Lee's Tables and Formulæ—

1′	=	1391.3
30″	=	695.7
1″	=	23.19
0″.573	=	13.29
1′ 31″.573	=	2123.48 = $6^s.105^m$

Hence we have—

	h.	m.	s.
Bismarck west of Du Luth	0	34	43.22
Du Luth west of north base			6.10
North base west of Washington	1	0	6.07
Bismarck west of Washington	1	34	55.39
Washington west of Greenwich	5	8	12.12
Longitude of Bismarck	6	43	7.51
	=100°	46′	52″.7

The probable error of this result cannot easily be computed. By the usual rules, it will be about $\mp 0^s.10$; but it is to be here noted that the personal equations are very thoroughly eliminated, and that the three determinations—

m.	s.
34	43.30
	43.21
	43.16

are very completely independent of each other.

LOCATION OF OBSERVATORY AT BISMARCK, DAKOTA TERRITORY, OCTOBER 20, 1873.

First measurement.—From center of pier due north to the north line of Main street, 501½ feet; thence due west along said north line of Main street, 84½ feet, to the northeast corner of Main and Fifth streets, known as "Mason's corner."

Second measurement.—From center of pier due north to the north rail of the main line of the Northern Pacific Railroad, 233 feet; thence due west along the same rail, 1,512 feet; thence due north 103 feet, to the flag-staff at Camp Hancock.

APPENDIX H H.

ANNUAL REPORT OF CAPTAIN W. A. JONES, CORPS OF ENGINEERS, FOR THE FISCAL YEAR ENDING JUNE 30, 1874.

EXPLORATIONS AND SURVEYS IN THE DEPARTMENT OF THE PLATTE.

FORT SCHUYLER, N. Y., *September* 25, 1874.

SIR: I have the honor to submit my annual report of operations as engineer-officer of the Department of the Platte for the year ending June 30, 1874.

The usual operations of the office have been carried on, viz, the collation of geographical information pertaining to the department, and its embodiment in maps, sketches, &c., for the use of officers conducting military operations within its limits; the survey of military reservations; and the reconnoissance of special areas concerning which information is incomplete or defective.

The beginning of the fiscal year found me in the field engaged in a reconnoissance of the country lying about the headwaters of the Yellowstone, Snake, Green, Wind, Big Horn, Grey Bull, Clark's Fork, and Stinkingwater Rivers, an excessively mountainous area, lying in the northwestern corner of Wyoming Territory, and largely unexplored.

As the region was one of rare interest to physical science, a geologist and botanist were secured. The small amount of funds in hand prevented the employment of more observers of this class. This reconnoissance was completed late in September, and a preliminary report at once prepared and submitted. The final report was finished and submitted early in the following May, shortly after which Congress ordered its publication.*

Besides the descriptive journal, it treats of the physical geography, geology, botany, meteorology, entomology, mineral and thermal waters, and general geography of the region. A new route to the Yellowstone Park and Montana from the southeast was discovered. It traverses a piece of country about the headwaters of Wind River that had previously been considered impassable and will probably become a highway. The outlines and character of a remarkable range of mountains, the Sierra Shoshone, lying between the valleys of the Yellowstone and Big Horn, were ascertained. This range was crossed for the first time by our party, and was previously almost unknown. The existence of four passes through it was found, two of which were discovered by us.

The survey was effected by means of a preliminary triangulation, checked by astronomical observations, and accompanied by thorough barometric measurements.

The report is illustrated, and accompanied by a general map of the region traversed compiled from the latest reliable data, together with detailed sketches of the topography of the country traversed each day.

After the completion of this reconnoissance, the ordinary office-work was resumed, and the following maps finished, viz:

Sheet No. 3 Department of the Platte, Wyoming Territory: General map of Department of the Platte, showing the movements of troops and expeditions during the year.

Sheets Nos. 1, 2, 3, 4, 5, of skeleton-map of Department of the Platte on an enlarged scale, for the use of scouting parties.

Map of the reconnoissance of Northwestern Wyoming. Two tracings of same.

Three tracings of west end of general map of the department.

Forty-five topographical maps of the reconnoissance of Northwestern Wyoming, showing details. Various tracings and sketches for the use of officers serving in the department.

Very respectfully, your obedient servant,

W. A. JONES,
Captain of Engineers.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

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* Printed in H. Ex. Doc. No. 285, 43d Congress, 1st session.

APPENDIX II.

ANNUAL REPORT OF LIEUTENANT E. H. RUFFNER, CORPS OF ENGINEERS, FOR THE YEAR ENDING JUNE 30, 1874.

HEADQUARTERS DEPARTMENT OF THE MISSOURI,
Fort Leavenworth, Kans., August 27, 1874.

SIR: I have the honor to submit the following report for the year ending June 30, 1874:

EXPLORATIONS AND SURVEYS IN THE DEPARTMENT OF THE MISSOURI.

The principal duty of this office being the organization of means for collecting and the arranging of information so gathered by the various scouting parties in the Department, it is gratifying to notice the rapid increase of mileage, and valuable journals recorded from year to year. The sum-total of journals recorded for the season of 1873 was 100; comprising special surveys, reconnoissances, examination of roads, and ordinary scouting-journals. The total mileage reported was 22,903 for the past year against 9,085 for the preceding. The movement of troops has not been any greater, but there has been greater attention paid to the journals. The principal improvement has been made in the district of New Mexico, where the presence of the engineer-detachment under my orders, the instructions given by them to private soldiers, and increased attention to the whole matter, have been productive of valuable results. A very fine collection of plats of roads and scouts was made during the season amounting to a very large mileage, and these, reduced to a uniform scale and embodied in a series of special plats, have been furnished to all directly interested. Attention is especially invited to the fact that all the information in the vicinity of Fort Tulerosa, and between Fort Tulerosa and Forts Wingate and Bayard and Camp Apache, (published in map-form,) has come from this office as furnished by the engineer office at Santa Fé. This was first published in a small, special map of the vicinity, and afterward on sheet No. 4 of the map of the Department of the Missouri. Since that time the plats of roads and scouts in New Mexico, (season of 1873,) already alluded to, will be found to contain much furnished by me in advance of other issues. In New Mexico the section of country also to the south and southeast of Fort Stanton has been quite thoroughly gone over by the command of Maj. W. R. Price, Eighth Cavalry, who seems to have been almost ubiquitous during the last season. From a cavalry-camp on the Canadian River, near Fort Bascom, a number of scouts under Capt. S. B. M. Young, Eighth Cavalry, over and near the Staked Plains, are recorded. One, a very long one, from old Fort Sumner over the Llano, and across the upper part of the Red River, and thence to Camp Supply, gives the most thorough description on record of a country now to be traversed, in part, by the expedition in the Indian Territory just organized. From Fort Dodge the ceaseless movement of cavalry during the entire season kept an accurate record of almost every settler on the Indian frontier; and from Fort Lyon a list of one thousand four hundred miles of carefully-recorded journals adds to our resources, and furnishes matter which is almost immediately called for again by the military at those posts.

This office now possesses very thorough descriptions of nearly all

roads in the department, and, in addition to this, is constantly employed giving attention to new and proposed routes, with a view to shortening and bettering communications. It was with this intention of giving detailed practical information on the resources of and communications with the mountainous regions of Colorado, where the threatened troubles with the Ute Indians might have made such valuable, that a reconnoissance partly in the Ute country was organized and sent out in May, 1873. This party examined the headwaters of the Rio Grande, Gunnisson's or Grand River, and the Arkansas, and their approaches. The report, accompanied by a map, was made to the Chief of Engineers, and published as executive document No. 193 of the House of Representatives at the last session. The running of a continuous azimuth and stadia line so long and difficult, crossing five high mountain-passes, was an experiment, and, as a successful one, I take pride in referring to the achievement. It originated in an effort to use the finished methods of the United States lake-survey on reconnoissance-work. I feel safe in inviting critical examination of the work as a finished and valuable survey so far as the instrumental line is concerned; and in view of discussions since arisen as to the value of the "meandering" method and of "reconnoissance" work, I here desire distinctly to state that until this work has been checked by a regularly-organized geodetic triangulation and proved incorrect, the manner and method gives it a claim to credit, not excelled by any kind of topographical work done in the mountains. Moreover, as the results are *immediately* available, they are therein of especial use at department headquarters, and to those who are interested in the region traversed.

This spring, commencing in the middle of May and completed in the middle of July, was made an examination by Lieut. G. S. Anderson, Sixth Cavalry, of a direct practicable wagon-route from Fort Garland to Fort Wingate. The link especially examined was a direct route from Conejos, Colorado Territory, to the headwaters of the Chama and Puerco Rivers, the remainder of the route having been proved available by Lieutenant Morrison in 1872.

Two instrumental lines were run, and a detailed report, with estimates, is in preparation, and will shortly be submitted, with maps. The importance of a direct and good communication from Fort Garland to Wingate and Northeast Arizona is easily seen, more especially when it is believed that the Denver and Rio Grande Railroad will shortly extend their line to Badito, and possibly over the range to the Rio Grande water-shed. An attempt was made to survey the proposed Indian and military reservations at Fort Tulerosa. The extreme length of the lines, (three hundred miles,) the difficult nature of the country, combined with the inefficiency of the civil engineer employed, resulted in the discontinuance of the survey after a portion had been run. The reservations will not be declared, owing to the proposed removal of the Indians to another place; further operations have been suspended.

At the close of the operations of the party of the Ute reconnoissance a survey was made by them of a reservation for the use of the signal-service on the top of Pike's Peak. This was completed in October; a report made, accompanied with plats; and a reservation, as proposed, was declared by the President.

In consequence of a private claim having been made on a part of the military reservation of Fort Leavenworth, Kans., a resurvey was ordered by the Secretary of War in May. This was ably done by my assistant, Mr. Donald W. Campbell, and a minute and accurate plat of this

large reservation of 6,900 acres was furnished, giving all the principal artificial as well as natural features.

I myself having been placed in charge of the completion of a military road from Santa Fé to Taos, N. Mex., made surveys during the fall of various roads in that vicinity, and in the spring I was engaged for four months on its construction.

The field-operations during the present season comprise mainly the notes to be taken under direction of Lieut. G. S. Anderson, Sixth Cavalry, acting engineer-officer during the expedition in the Indian Territory, and the scouts in New Mexico, where the engineer-detachment is still on duty. There being no funds for the use of surveys, &c., this year, none are contemplated. The office-work has consisted of the platting of the various scouts and marches. Tracings of these were also made and furnished the engineer-office at headquarters of the Military Division of the Missouri.

At any interval of leisure for the last three years, the preparation of a map of the Indian Territory has been slowly going on; and during the past winter the reception of the many land-survey plats of the two preceding years' work gave a great deal additional.

I laid off and platted, myself, a large part of these surveys, and the remainder have been put on by the draughtsmen, and now the greater part of the Territory is delineated on a scale of $\frac{1}{500000}$. When commenced, this work seemed extra, the territory not belonging to this department; the wisdom of it was, however, seen when the transfer to this department of half of the territory, and the sudden organization of a large expedition, called for the best map I could furnish. For two weeks the entire force of this office was at work making tracings of what was completed, and as much more reliable matter as could be safely added.

The preparation on stone of the preliminary map of the Ute reconnoissance occupied the principal draughtsman, A. Hunnius, a month and a half in the winter.

The second draughtsman, Samuel Anstey, afterward made a corrected map of the same on paper when recalculation had changed many positions. Mr. Anstey also made on an enlarged scale a sketch showing the mining-regions of the San Juan district.

And Mr. Hunnius made a very handsome sketch of the Philosopher's Mounts, so called, a portion of the same reconnoissance. The preparation of the report of the Ute reconnoissance occupied the entire force of the office for two months. When sent, a revision of the calculations and the general tables was made by Mr. Campbell, and the meteorological observations were partially gone over again. During the year, a volume on a uniform scale of $\frac{1}{1000000}$ of the various roads and scouts in New Mexico reported during the season of 1873 was prepared and sent to the Engineer Bureau, and I was much pleased at the receipt of a commendatory letter thereupon.

During the year, the engineer-detachment in my charge have conducted themselves very creditably in the discharge of their duties, and have, in addition to the duties in the field, performed creditably their office-work.

Sergeants R. N. Harper and G. A. Lichtenberg have been of material service in the preparation of the Ute reconnoisance report, and Private Winckler as draughtsman and clerk in the engineer office, Santa Fé, New Mexico.

In the issue of maps from this office, the total number of maps of the

Ute reconnoissance is included, these having been bound with the report as printed.

Maps issued during the fiscal year ending June 30, 1874.

Map of vicinity of Fort Tulerosa	13
Roads from Fort Dodge to Camp Supply	12
Map of Chickasaw country	29
Western Territories	2
Map of Indian Territory, Lieutenant Jackson	3
Map of Kansas, Lieutenant Jackson	1
Kansas campaign	31
Department of the Missouri, sheet 2	70
Department of the Missouri, sheet 4	404
Ute reconnoissance	925
Tracings	63
Total	1,553

Financial statement.

During the year the expenditures of the office have been	$10,000
Amount available for fiscal year ending June 30, 1875	3,200
Amount applied for for fiscal year ending June 30, 1876	10,000

COMPLETION OF MILITARY ROAD FROM SANTA FÉ TO TAOS, NEW MEXICO.

This work, authorized by act of Congress approved March 3, 1873, was placed under my charge by paragraph 7, Special Orders No. 133, War Department, Adjutant-General's Office, Washington, July 3, 1873.

Under instructions from the Engineer Bureau I proceeded to New Mexico in September, 1873, and made preliminary reconnoissances of the various routes, and a survey of the one selected for operations.

My preliminary report and a proposed plan was then forwarded to the Chief of Engineers and received his approval, and I was authorized to construct the road myself under my own personal supervision.

It seems hardly necessary to expand further than to state that the work contemplated was in the cañon of the Rio Grande between the villages of La Joya and Cienigilla, in the location recommended by Capt. J. N. Macomb, Corps of Engineers, in 1859, and afterward the subject of a memorial from the legislature of New Mexico to the Congress of the United States. On either side of the points named are good roads from Cienigilla to Taos and from La Joya to Santa Fé; but the intervention of the high mountain-spur which caused the cañon was only to be overcome by hard work. During the winter, supplies were purchased and sent forward, and early in March I left for Santa Fé. A severe and prolonged winter had blocked the roads, supplies were delayed, and commencement of work was a month later than calculated upon. About April 1 work was fairly commenced in the middle of the cañon at the village of Rincoñada, and pushed forward with miners and laborers as fast as was practicable.

The original plan contemplated crossing the Rio Grande twice by means of crib-pier bridges, and early in the fall orders had been given for logs and lumber for the same. Unfortunately, however, both of the parties failed to fill the orders in time, and it became imperative not to waste time, but to push up on the left bank of the river. The result was heavy work and a largely-increased expenditure, not only from the

nature of the work, but because the partially-completed work on the other side of the river and at the bridge-sites was lost.

Communication was, however, opened by the third week in May. The remainder of the appropriation was expended in the cañon from La Joya to Embudo, to avoid the high hill now crossed on that road. A narrow road was pushed through this to the farthest point possible, leaving about three-fourths of a mile unfinished to complete the through-road. If this were finished, the road from Santa Fé to Taos would be of excellent grades, excepting at one place, the Arroya Honda, and would be one of the best roads for its length of seventy miles in the Territory. As it is, heavy freight is only interfered with by one sharp rise between Embudo and La Joya, which can easily be lightened over. In light travel from the end of the railroad to Santa Fé, forty miles can now be saved by passing via Cimarron, Taos, and the new road, and communication with Fort Garland from Santa Fé has been much bettered.

During the entire working-season I was assisted by Lieut. C. C. Morrison, Sixth Cavalry, acting engineer-officer district of New Mexico, to whom I am indebted for his watchfulness, energy, and perseverance in carrying out duties intrusted to him.

	Miles.
Distance from Santa Fé to Taos, United States mountain road	87.75
Distance from Santa Fé to Taos, via Ojo Caliente	80.50
Distance from Santa Fé to Taos, (new road)	70.00
Of this road miles worked in the upper cañon, (new road)	11.83
Of this road miles worked in the lower cañon	2.50
Number of miles repaired between La Joya and Embudo	6.00
Total miles worked	20.83

The accompanying skeleton-map will illustrate the principal connections.

Appropriation for completion of military road from Santa Fé to Taos, N. Mex., $25,000, of which, including contracts still unpaid, all has been spent.

Very respectfully, your obedient servant,

E. H. RUFFNER,
First Lieutenant of Engineers

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

APPENDIX K K.

ANNUAL REPORT OF CAPTAIN WILLIAM LUDLOW, CORPS OF ENGINEERS, FOR THE FISCAL YEAR ENDING JUNE 30, 1874.

EXPLORATIONS AND SURVEYS IN THE DEPARTMENT OF DAKOTA.

HEADQUARTERS DEPARTMENT OF DAKOTA,
OFFICE OF THE CHIEF ENGINEER,
St. Paul, Minn., September 7, 1874.

SIR: I have the honor to forward herewith copies of my annual report to the department commander, together with the preliminary

reports of the reconnoissance to the Black Hills, by Professor Winchell, Mr. Grinnell, and myself.

Very respectfully, your obedient servant,

WILLIAM LUDLOW,
Captain of Engineers.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

ANNUAL REPORT TO DEPARTMENT COMMANDER.

OFFICE OF CHIEF ENGINEER,
HEADQUARTERS DEPARTMENT OF DAKOTA,
St. Paul, Minn., September 5, 1874.

SIR: I have the honor to make the following report of the operations of my department since October 1, 1873:

During the fall and winter I was engaged in examining the reports of journeys by officers in the department, and plotting the trails, when any information could be obtained from them. In the great majority of cases, these itineraries and maps are valueless, sometimes on account of a want of proper instruments, but generally because the officer will not take the necessary trouble in addition to the routine duties of his daily march. I shall endeavor to provide the instruments, and the work can best be done by an intelligent enlisted man, suitably instructed and specially detailed for the duty.

The revision of the official map of the department was continued until the spring, and authority obtained for the publication of a new edition, which will soon be ready for distribution.

In accordance with instructions contained in Special Orders No. 11, current series, from these headquarters, I proceeded to Fort Ripley, Minn., on May 29, and made a survey of the vicinity, at the same time marking the limits of a reservation one mile square, recommended in the report of the board convened at Ripley for that purpose.

A map was prepared, and accompanied the report of the board.

Special Orders No. 117 directed me to accompany the Black Hills expedition as engineer officer. I was unable, on account principally of lack of funds, to make any extended preparations for the trip, or to secure the services of as many skilled and instructed gentlemen as I desired. I had no funds with which to pay salaries. Nevertheless, Professor Winchell, State geologist of Minnesota, and Mr. G. B. Grinnell, representing Professor Marsh, of Yale College, accompanied the expedition under my direction. A photographer was fitted out mostly from the apparatus used on the Yellowstone expedition of last summer, and took very successful views.

A preliminary report of the expedition, accompanied by similar reports from Professor Winchell and Mr. Grinnell, will be submitted in a few days.

The detailed reports and map of the route cannot be completed under two months; the time being also required by Winchell and Grinnell for a proper examination of their geological and zoological collections, and a full study and digest of the information obtained.

The whole will be submitted at the earliest practicable day.

Very respectfully, your obedient servant,

WM. LUDLOW,
Captain of Engineers, Chief Engineer Department Dakota.

The ASSISTANT ADJUTANT-GENERAL,
Department of Dakota.

PRELIMINARY REPORT OF RECONNOISSANCE TO THE BLACK HILLS.

ST. PAUL, MINN., *September* 7, 1874.

SIR: The expedition [under the command of Lieutenant-Colonel Custer, Seventh Cavalry,] was organized for the purpose of exploring the unknown territory lying principally in the western and southwestern portion of Dakota and the eastern portion of Wyoming, with a view of discovering practicable interior military routes between Fort Lincoln, in the Department of Dakota, and opposite the terminus of the Northern Pacific Railroad, and Forts Laramie and Fetterman, in the Department of the Platte, with the Union Pacific Railroad for their base. In case circumstances should at any time require the establishment of military posts in the region referred to, a more exact knowledge of its resources than we possessed would also be required to guide in the selection of suitable sites.

I was directed by the department commander to accompany the expedition and act as its engineer officer.

Unable to obtain funds which would be available for the payment of salaries, I nevertheless secured the services of Prof. N. H. Winchell, of Minneapolis, to act as geologist for the expedition, and of Mr. G. B Grinnell, representing Professor Marsh, of Yale College, who kindly agreed to report upon the paleontology and zoology of the region to be traversed. Professor Winchell would also make such report as his time might afford upon the botany of the Hills; and Dr. Williams, assistant surgeon United States Army, and medical officer of the expedition, promised to aid in the same department.

A photographer was fitted out with apparatus and chemicals and a spring-wagon constructed for similar use on the Yellowstone expedition of 1873.

For the surveying I had my detachment of engineers, consisting of two sergeants and four men, who were to keep two sets of notes of the route with prismatic compass and odometer, while my assistant, Mr. W. H. Wood, and myself, would attend to the general topography and the astronomical observations for latitude and longitude.

The expedition left Fort Lincoln on July 2, and consisted of ten companies of cavalry and two of infantry, with a battery of three Gatling and one Rodman gun, and a detachment of Indian scouts, guides, &c. The train consisted of over one hundred wagons.

We were assured by the guides of two things in advance: first, that the expedition would be strenuously opposed by a hostile force of Indians; secondly, that we could never penetrate the fastnesses of the Black Hills. They represented the difficulties in our way as being formidable for cavalry, and for wagons insuperable. Both predictions failed. The expedition returned to Fort Lincoln on August 30, the sixtieth day out, with a loss of but four men—three from sickness and one killed in a quarrel—having seen no hostile Indians during the whole trip of nearly one thousand miles, and having thoroughly explored the Black Hills from east to west and from north to south.

The route pursued led us up the south side of Heart River; thence, in a general west-southwest direction, across the Cannon-Ball and up the north fork of Grand River; thence southwestwardly to a point which we named Prospect Valley, in about latitude 45° 30′ and longitude 103° 40′; thence, up the east side of the Little Missouri River and southwardly, to the north fork of the Cheyenne River, known as the Belle Fourche.

This point we reached on July 18, in about longitude 104°, after sixteen marches and three hundred miles of travel.

Hitherto the country had much resembled other portions of Dakota; an open prairie; wood scarce, and only found in river-valleys; water not always to be met with in sufficient quantity, and frequently impregnated with salts, which was both disagreeable and injurious; but still with a fair amount of grass, and presenting no serious difficulties to the traveler.

All the country bordering on Heart River is good; that on Cannon-Ball is fair. Grand River country is poor as well as that near the headwaters of the Moreau, or Owl River.

All these streams flow east and head close up to the Little Missouri, which running northward at right angles to the others, has but a narrow and barren belt tributary to it on the east side. Its main support is from its branches heading in the Powder River range of hills.

Our route led us in view of Slim Butte, which is rather a high steep coteau than a butte, of Slave and Bear Buttes, and many others not hitherto located; and the Black Hills, as we approached them, looked very high and dark under their covering of pine-timber.

We crossed the Belle Fourche on the 20th July, and found ourselves transported to a new country. The whole character of our surroundings was changed. There was an abundance of grass, timber, small fruits, and flowers, and, what was perhaps better appreciated than all, an ample supply of pure cold water; and these advantages, with a few exceptions, we enjoyed until we left the Hills for the return-journey.

Our course lay up the valley of the Redwater—a large branch of the Belle Fourche—to Inyankara; thence easterly and southeasterly into the heart of the Hills, valley leading into valley, to the beautiful park-country, always until now marked unexplored on the maps, of which we had heard much, but hardly hoped to reach with our wagons.

After arriving near Harney's Peak, a lofty granite mass, with an altitude of over 8,000 feet above the sea, and surrounded with craggy peaks and pinnacles, a rapid scout was made to the south fork of the Cheyenne, nearly due south of us, with five companies of cavalry, and the exit from the interior shown to be not difficult on that side.

Returning, the course lay northerly and northeasterly, looking for an exit near Bear Butte. Failing to find an easy one, we went southerly a short distance, and discovered a pass near Elk Creek, which let us out on the prairie. The change to the hot dry air and yellow grass of the prairie was wonderfully sudden and anything but pleasant.

From Bear Butte, the return-journey led back past Slave Butte, touching the headwaters of the Moreau, crossing the down-trail in Prospect Valley; thence tapping the head of Grand River, and following roughly the east side of the Little Missouri northward and eastward to where the trail of the Yellowstone expedition crosses it; thence into Lincoln on the north side of Heart River.

The return-route was a much better one for a large force than the other. We had no difficulty in finding good camps with plenty of water and grass. The country passed over tributary to the Moreau is barren, but the river-valley itself is more favorable, and at the head of Grand River is much better country than lower down. From Grand River to above Heart River the grass had been thoroughly burned by the Indians. It caused some inconvenience, but we were always fortunate in finding a camp in some localities which the fire had spared.

With regard to the geology of the Black Hills, Professor Winchell's report will be nearly exhaustive. Both Mr. Grinnell and he were as

industrious as possible in collecting information, and I can only regret that the time available prevented as much opportunity for study as they could have improved. I beg to call attention to the preliminary reports from both gentlemen presented herewith. Their detailed reports will be prepared as soon as possible, as well as one from Dr. Williams on the flora of the hills.

It is a region admirably adapted to settlement, abounding in timber, in grass, and flowing streams, with springs of pure, cold water almost everywhere; the vallies of gentle slope, and ready for the plow; the soil of wonderful fertility, as evidenced by the luxuriance of the grass and the profusion of flowers and small fruits; the climate entirely different from that of the plains, giving evidence of being much more agreeable; cooler in summer and more moderate in winter; not subject to drought, for the nightly dews are very heavy; not liable to excessive snow-fall, for in narrow valleys containing a large creek no indications of overflow could be detected.

The creeks confine their favor to the hills. Upon reaching the exterior range, they pass through rocky cañons, sometimes of great depth, and arriving at the outer foot-hills sink into the ground and disappear.

Upon the mineral resources of the hills, Professor Winchell's report will throw full light. No coal was found. Extensive deposits of iron ore of good quality exist; immense beds of gypsum were met with; specimens of gold were washed from the soil in the vicinity of Harney's Peak, and quartz in bed and bowlder was visible in large quantities. A specimen of something which the discoverer believed to be silver, but which more resembled platinum, was shown me. Plumbago also was found in small quantities.

Any amount of excellent building-stone, limestones, sandstones, and granite exist. Some of the limestones, particularly in the vicinity of Inyankara, were fine enough for marbles and handsomely colored.

The timber is mainly red pine and spruce, of large size; oak, ash, and elm are found on the exterior slopes. Game is abundant. Bear, elk, and deer of two kinds were found and many killed. On the prairies the antelope were found in large numbers.

The complete report, accompanied by the reports of Professor Winchell, Mr. Grinnell, and Dr. Williams, will be transmitted at the earliest possible day, together with a map showing the route pursued, with bordering country from Fort Lincoln and return, and a special map on a larger scale of the Black Hills proper.

The photographer secured negatives for about sixty views, a set of which will accompany the report.

Respectfully submitted.

WILLIAM LUDLOW,
Capt. of Engineers U. S. A., Chief Engineer Department of Dakota.

The ASSISTANT ADJUTANT-GENERAL,
Department of Dakota.

PRELIMINARY GEOLOGICAL REPORT BY PROF. N. H. WINCHELL.

THE UNIVERSITY OF MINNESOTA,
Minneapolis, September 8, 1874.

DEAR SIR: In accordance with your request, I herewith give you a brief statement of the work done by me in the late exploration of the Black Hills by General G. A. Custer, indicating at the same time some of the most important geological results that are

likely to come from the reconnoissance. It is plain to see that in the absence of the specimens collected, none of which have yet arrived at Minneapolis, this report is based on field-notes and impressions received in the field, and lacks that authentication that is derivable only from a careful study of the fossils.

In passing over the plains between Fort Lincoln, on the Missouri River, and the Black Hills, there was but little opportunity to fix certainly the western limit of the Cretaceous, or to determine the area of the Tertiary. A few fossils were gathered near the Little Missouri River, and careful notes of exposed sections of rock were taken at all accessible points. At a number of points, beds of lignite were seen, and they will be expressed on the geological map intended to accompany the final report. In crossing the plains, the expedition traversed a district that had never before been visited and reported on by any geologist. Dr. F. V. Hayden, in a final report on the geology of Nebraska, has, however, published a geological map showing the presumed areas of the Tertiary and Cretaceous in that portion of Dakota. Without intending here to deny the correctness of that map, I may state that the impression received from lithological evidence would reduce very much the area of the Tertiary and increase relatively that of the Cretaceous. The Cretaceous area that Dr. Hayden represents along the valley of the Missouri River at Fort Lincoln seems to extend much farther west than has been supposed. Very important beds of lignite occur in it on both sides of the river, in the vicinity of Fort A. Lincoln, and they seem not to be restricted to the Dakota group. On this question, the fossils collected may throw some light when they shall have been examined. They have been submitted to Prof. Marsh, of New Haven, Conn.

In entering the region of the Black Hills proper, the evidences of disturbances begin to appear on the plains about twenty miles before reaching the Belle Fourche, along our line of march. The shales and clays here begin to show a changeable dip, and are more or less slaty, and deepened in color to a dark purple or black. A considerable clay ironstone is scattered over the surface weathered from the beds, and, by drainage and erosion, the rock, which is easily disintegrated, is wrought into a series of ravines and low bluffs. This aspect is most marked at our first crossing of the Belle Fourche, where the Fort Pierre group forms an exposed thickness of slate and slaty shale between three and four hundred feet. From the Belle Fourche, the formations passed over in entering the Hills come in the following order:

	Feet.
1. Purplish or black slate, Fort Pierre	300–400
2. Sandstone, Dakota, about	500
3. Green shale, Dakota	45
4. Fossiliferous conglomerate	2
5. Purplish shale, toward the top arenaceous	10
6. Snowy gypsum	4–6
7. Red shale, massive or laminated	75
8. Snowy gypsum	22
9. The same as No. 7	18
10. Snowy gypsum	2½
11. The same as No. 7	30
12. Snowy gypsum	2½
13. The same as No. 7, and slope	35
14. Fine-grained limestone, on which the last lies unconformably; this is known as the carboniferous limestone, about	100
15. Harsh, arenaceous, magnesian limestone, about	75
16. White massive sandstone, about	75
17. An immense limestone formation, stretching over a large area in the northern portions of the Hills, capping hundreds of buttes and bluffs; this is a light-colored, often saccharoidal, variable limestone; it is hard, and usually of a compact texture	225
18. Hard red limestone, with chert and cyathophylloid and crinoid joints	16
19. White coarse sandstone, with small rounded quartz pebbles	25
20. Red sandstone, with glauconitic particles, perhaps 25 feet, seen only	10
21. Conglomeritic sandstone, white	30–40
22. Metamorphic schists and slates.	
23. White feldspathic coarse granite.	

Sections were observed in the southern portion of the Black Hills, in which a reddish quartzite was conspicuous, immediately overlying the metamorphic slates, and forming the surface-rock over the tops of a great many hills. In some places, also, a shaly sandstone is associated with Nos. 19 and 20, and contains *Obolila* and *Lingula*.

In respect to the economical products of the rocks of the Black Hills, the following minerals exist in considerable quantities, and will ultimately be found very useful:

Gypsum in unlimited quantities; variegated marble from the Carboniferous limestone; iron-ore in the southeastern portion of the Hills; muscovite; talcose slate, useful for whetstones.

There may be found, also, other products of the granite rocks; indeed, the miners

that accompanied the expedition report the finding of gold and silver in some of the gulches in the southeastern portion of the Hills, though I saw none of the gold; nor did I see any auriferous quartz. I have taken the gold-reports with a large grain of allowance.

The granite center of the Black Hills is in the southern and southeastern portions.

The whole of the region was explored, so as to determine the general geological structure, excepting a range of hills in the southwestern part, the composition of which is presumed to be of the sedimentary rocks above the Potsdam. The Hills die out toward the south much more rapidly than toward the north. The most practicable routes for entering the Hills are from the north.

A large part of the Hills, especially in the north, are composed of slightly-tilted sedimentary rocks, cut by erosion into bluffs, buttes, and ridges, separated by valleys that generally are well watered, often grassed, and arable.

The Hills have a delightful climate, pure water, abundance of pine-timber, and a sufficient quantity of arable land to sustain a thick population.

Very respectfully submitted.

N. H. WINCHELL.

Col. WM. LUDLOW,
St. Paul, Minn.

PRELIMINARY REPORT ON PALEONTOLOGY, BY MR. GEO. BIRD GRINNELL.

SIR: The rapidity with which General Custer's command traveled, the long marches and brief halts, precluded any but a very hasty and incomplete exploration of the country passed through. No small camping-ground would accommodate so large a force as the one in question, and, as might readily be supposed, the country best adapted for the discovery of fossil remains is that least fitted for camping-purposes on account of the lack of wood, water, and grass. Thus the very days on which, with the greatest degree of probability, fossils might be expected, were usually those on which the longest marches were made.

Of course, under such circumstances it was necessary to pass by many large areas of washed bluffs without even a cursory survey, and this was especially the case on the 14th day of July, on which day the first vertebrate remains were discovered. Enough, however, was seen to assure me that the localities traversed were by no means rich in fossils, and that but limited collections could have been made even had I more time to devote to their examination. In the present brief notice, I propose merely to touch upon the discoveries made, reserving all scientific details for a future report, to be made as soon as the few specimens collected can be identified and their geological horizon determined with accuracy. This, it is hoped, may be accomplished in a few weeks.

Starting from Fort Lincoln, July 2, and passing over a rolling prairie for about twenty miles, the first fossils were found July 3, near the summit of a small butte, and just beneath the layer of friable brown sandstone with which all the surrounding buttes were covered. These consisted merely of a few Cretaceous shells, bivalves, a gasteropod and a cephalopod, all much weathered and so fragile as almost to crumble while being picked up.

From this point until we left Ludlow's Cave, July 12, no bad lands were seen, but on the 13th, several washes were visited and thoroughly explored, but all proved barren of fossils. On the 14th, the country became much more rugged and barren. High bluffs and mounds of blue clay, and without vegetation, were numerous, so much so that we were unable to visit all of them. At Castle Butte we found the first Tertiary remains of the trip, a few turtle-bones much worn by the weather, and a single leg-bone of a mammal of mammoth size, the latter so much cracked and shattered by pressure that I was unable to transport it to camp.

At some very extensive bad lands at the northwest point of Short Pine Buttes, two large vertebræ were discovered together with a few chelonian bones, and here, I think, was the most promising locality that we visited during the trip. But the time to examine them was wanting, and we were obliged to leave them without a proper exploration.

While in the Black Hills, a few Palæozoic fossils, chiefly brachiopods, of various kinds, were found, which will be enumerated in a future report; nothing, however, of general interest was observed until August 17, when a few concretionary fossils were found in the black shale northwest of Slave Butte. These were Cretaceous bivalves and cephalopods, and the limestone concretions in which they were found lay in position in the shale.

It is much to be regretted that the time allowed for investigation in this branch of natural science was so short, and it is earnestly hoped that another year a more

thorough and careful exploration of this region may be made, and more interesting results obtained.

In concluding this brief review, I must heartily thank General Custer and Colonel Ludlow for their constant willingness to assist me in every way possible consistently with the best interests of the expedition.

Your obedient servant,

GEO. BIRD GRINNELL.

Col. WM. LUDLOW,
Chief Engineer, Department of Dakota.

PRELIMINARY NOTICE OF ZOOLOGY, BY MR. GEO. BIRD GRINNELL.

SIR: In accordance with your request made to me while at Fort Lincoln, viz, that I should make such notes on the zoology of the region as I could in connection with my other duties, I have to report that, although my opportunities for zoological observations and collections were very limited, owing to the rapidity of our travel and the necessity of devoting all my time to the collection of fossils, I observed nearly thirty species of mammals, about one hundred and twenty species of birds, and a few reptiles. A full enumeration of the animals observed, together with such observations as I was enabled to make upon their habits, will appear in a detailed report, which I shall have the honor to make to you as soon as praticable.

As a game-country, the Black Hills will compare very favorably with any locality in the country. Deer of two species are most abundant, the white-tailed deer especially being so numerous about the headwaters of Elk Creek that one hundred were killed by the command in a single day. Elk, from the indications, are numerous, although only a few were killed. Several bears were secured, and not a few exciting incidents occurred during their capture. No mountain-sheep were obtained, although there were many indications of their presence, and a single female was seen.

Almost all the streams which we passed were dammed in many places by beaver, and fresh tracks and signs were very plenty. Game-birds are well represented by several species of geese and ducks, which are to be found along the various water-courses in and about the Hills, and by at least two species of grouse, the sharp-tailed and the ruffed. The former are numerous along the open valleys and on the sparsely-wooded hill-sides, and the latter among the dense pines of the higher land

Altogether, the Black Hills offer to the sportsman abundance and variety of game, and if opened to the white man will be as much esteemed as a hunting-ground by him as they now are by the Indians.

The fuller details which I shall present later will, I trust, be found interesting to the zoologist, as presenting information on the fauna of a region of which so little has been told.

Yours respectfully,

GEO. BIRD GRINNELL.

Col. WM. LUDLOW,
Chief Engineer Department of Dakota.

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